

Sacrificial anodes for protection of seawater pump caissons against galvanic corrosion

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ABSTRACT

If unprotected, seawater lift pump caissons can suffer severe galvanic corrosion. Within 2-5 years holes in the caisson can appear. The corrosion to the steel caissons is caused by the noble pumps and risers, which normally are made of Ni-Al-bronze, and/or (super) duplex stainless steel. If the caisson is not protected by a coating, corrosion rates of 2-5 mm/year are reported. For coated caissons, corrosion rates of more than 10 mm/year have been seen. This extreme high rate is caused by galvanic current concentration in small coating defects.

This article will describe how corrosion was stopped on coated caissons on a FPSO. Also installation of a cathodic protection system for relatively smaller pumps on two platforms in the Northsea will be discussed. Intensive reference cell measurements confirmed that the position of the sacrificial anodes is crucial. For this reason an effective way of hanging the anodes in the annulus of the pump and riser in the caisson was developed. Duplex and super duplex stainless steels should not be protected at levels more electronegative than -900 mV Ag/AgCl. This is achieved by a potential control unit on the sacrificial anode assemblies.

INTRODUCTION

Seawater lift pumps are being used on offshore platforms and FPSO's for several decades. The materials selection for the pumps normally is Nickel-Aluminum-Bronze, duplex

stainless steel 2205 or super duplex stainless steel 2507. The riser has been made of duplex or super duplex stainless steel and the caissons are made of structural carbon steel. Often none of the three previously mentioned parts have been provided with a protective coating, however in practice all variations are noted; pump coated, riser coated, caisson coated, or a combination.

In the nineties, severe galvanic corrosion of the caissons was reported. Currently, unprotected caissons and pumps are being installed in new FPSO's and platforms without any adequate protection, or with insufficient protection. Probably the reason for this is that the pumps themselves are not corroding, they cause galvanic corrosion to the caissons. Manufacturers of pumps are different from caisson fabricators. This leads to the assumption that this potential corrosion problem has been neglected or under estimated for all these years.

The damage on FPSO's can be as high as several million USD within a couple of year caisson lifetime. Repair normally is not in a yard, but often during oil and gas production at sea. The ballast tanks need to be dried, scaffolding must be made and caissons (partially) must be renewed. For a pump with 20" riser diameter, normally the caisson diameter is 1 meter with a length of 25 meter and a WT of 20 mm.

CORROSION MECHANISM

The damage is caused by galvanic corrosion. If free in seawater, the potential of duplex stainless steel is about +100 mV Ag/AgCl. The potential of the carbon steel caisson, if free in seawater is approximately - 550 mV Ag/AgCl. This potential difference between the noble behaving pump and riser and the caisson cause a galvanic current of several amperes. As the current will choose the lowest resistance path, most corrosion will take place at largest pump diameter position. For the riser most corrosion occurs at the flange position. This often leads to a negative print of the flange in the caisson, visualized as circumferential grooves and holes. At the end, the caisson is cut by a process similar to electrochemical machining.

If the riser and pump have been coated, the system resistance increases which means that the current and corrosion rate decrease. However, by only coating pump and/or riser, corrosion is not stopped. This especially is the case at the pump inlet position, where a reliable coating cannot be applied on the inlet strainer mesh. Besides that, sooner or later the coating breakdown factor will increase, leading to higher currents and corrosion rates.

If an unprotected caisson has been coated, local corrosion rates will increase strongly. The galvanic current will concentrate on coating damages. The size of the damage can be microscopic small; caisson coating never will stop the galvanic corrosion problem. In contrary, if no cathodic protection system has been installed, the problems will be increased to local corrosion rates of >10 mm/year. Figure 1 shows holes in a coated caisson.

Most corrosion occurs at pump inlet position. Here the pump diameter is relatively large but also most water flow occurs at this position. Below the inlet the water flow is relatively high as well, which implies that more corrosion can be expected in this region. The higher corrosion rate is caused by the shorter distance between noble stainless steel and ignoble steel. Besides that, the water flow increases the transport rate of Oxygen at this location. At lowest part of the caisson, normally no corrosion occurs because the cathodic protection system of the platform or FPSO also will protect the first 1 or 2 meter of the caisson length. Above the inlet the water flow is much lower; however, for FPSOs it should be taken into

account that there always will be a motion stimulated flow due to the rolling of the vessel and for platforms some flow will be caused by the swell.

CATHODIC PROTECTION

Installing sacrificial anodes on the riser occasionally is done since the introduction of this type of pumps. Normally a cathodic protection (CP) design or CP measurements were not performed. Effective functioning of the CP system was assumed by installing anodes on the riser, and sometimes below the pump. During diver inspections large holes were found in the caissons on pump inlet position. The reach of the CP electric field is very limited in the narrow annulus between pump/riser and caisson. For that reason, adequate protection will be provided to the area near the sacrificial anodes installed. Depending on annulus dimensions, materials selection and use of coatings, the reach in the annulus is 0,5-1 meter (see figure 2). This implies that anode distance should be 1-2 meter. The length of a pump + motor for a 20" pump is approximately 4 meters. The only way of protecting the inlet area is installing anodes on the pump itself [2]. However; this is not desirable because the pumps and motor are relatively sensitive equipment which should not be impacted by any destabilizing weights such as depleting anodes. For that reason, pump manufacturers may void warranty if anodes are installed. By hanging the anodes in the annulus this problem can be avoided as the pump and motor are not touched by any anode or coating.

The anodes are hung on a bracelet that has been installed on the riser. See figure 3 and 4. By using 10-sided stainless steel rings and Nylon centralizers to the caisson, a very stable hanging construction can be made with a very long lifetime. The anode lifetime can be calculated in accordance with DNV RPB401. For a 10 years life relatively low weight is required as the surface to be protected is relatively small. The typical total anode weight for 10 years lifetime on a 20" riser, pump and caisson (all uncoated) is 125 kg Aluminum. It's not the total anode weight that is critical; it's the distribution of the anodes over the caisson surface. The ideal protection potential of the carbon steel caisson is -800 to -900 mV Ag/AgCl. The aluminum sacrificial anodes will polarize the nearby duplex stainless steel or Ni-Al-bronze riser to a similar potential. Figure 5 and 6 show pictures of the anode hanging construction.

POTENTIAL CONTROL

For duplex stainless steel and super duplex stainless steel, the potential preferably should not be lower than -900 mV Ag/AgCl. Below this potential, welded zones, or zones at high stress, can suffer Hydrogen embrittlement due to the cathodic reduction of H^+ to Hydrogen [1]. A circuit board was developed to control the potential upon a Zinc-reference probe. This electronic circuit has no internal resistance, and no threshold Voltage, meaning the anodes can deliver full power if required. In order to achieve a – and + pole, the anodes are insulated from the pump/riser/caisson. For this, Nylon washers and rings are used. The print board is powered by the sacrificial anode itself. To achieve charging at very low Voltage (0,15 V), Germanium transistors and an electronic circuit for charging a capacitor are used.

A capacitor is charged to 9 Volt during 1 minute, where after this Voltage is used to power the circuit board. As the current consumption is extremely low, similar to the current consumption of a smoke detector, the circuit board can be powered for long time, where after the capacitor is re-charged automatically. If required due to high resistance systems (such as coated steel), instead of a self-powered system a 9 Volt battery with a lifetime of

its own depletion (5 years) can be used. The potential control unit also is used for other applications such as fresh water sandbed filters and (sea) water condensers. The electronics have been installed in a stainless steel subsea enclosure. Figure 7 shows an anode assembly with tank anodes and a stainless steel potential control unit with reference probe.

INSPECTION AND MONITORING

This delicate and expensive equipment can be inspected or monitored by using Ag/AgCl half cells. Such cells can be descended in the annulus once a month and readings can be recorded. Another option is to install a permanent halfcell or Zinc reference probe, near the pump inlet. In this way, online monitoring to the DCS is possible, where an alarm can be set if the potential rises (more electropositive) than -800 mV, depending on design specifications. Similar inspections can be done in existing pump caissons, if any under protection is expected.

CONCLUSIONS

- Seawater lift pump caissons can suffer extreme galvanic corrosion; corrosion rates of more than 10 mm/year have been reported.
- Coating the riser and pump will help to reduce the corrosion rate; however it will not stop the corrosion, especially at pump inlet position.
- If no cathodic protection system installed, coating the caisson will increase the local corrosion rate as galvanic corrosion currents will concentrate on coating defects.
- Installing anodes only above and below the pump/motor will not protect the inlet area of the pump.
- Mounting anodes on the pump or pump motor is not desirable. The best solution is hanging the anodes on strategic positions in the annulus pump-caisson or riser-caisson.
- Optimal corrosion control is achieved if the sacrificial anodes are made 'potential controlled' by using an anode-powered potential control circuit. The best protection range is -800 to -900 mV Ag/AgCl.
- With a proper cathodic protection design, coating the pump, riser or caisson is not required. By hanging the anodes in the annulus, the pump and motor are not touched in any way.
- Regular and careful inspection should be performed either by descending half cells or Zinc-reference probes in the annulus or monitoring with a fixed probe on pump inlet position (this can be tied into a communication system or data-logger if necessary).

References

[1] Svern Magne Wigen, Harald Osvoll: Corrosion problems in seawater pump caissons. Practical solutions.

[2] P. Woolin, W. Murphy: Hydrogen embrittlement stress corrosion cracking of super duplex stainless steel. Corrosion 2001 (NACE).



Figure 1: Holes in the caisson within two years lifetime.

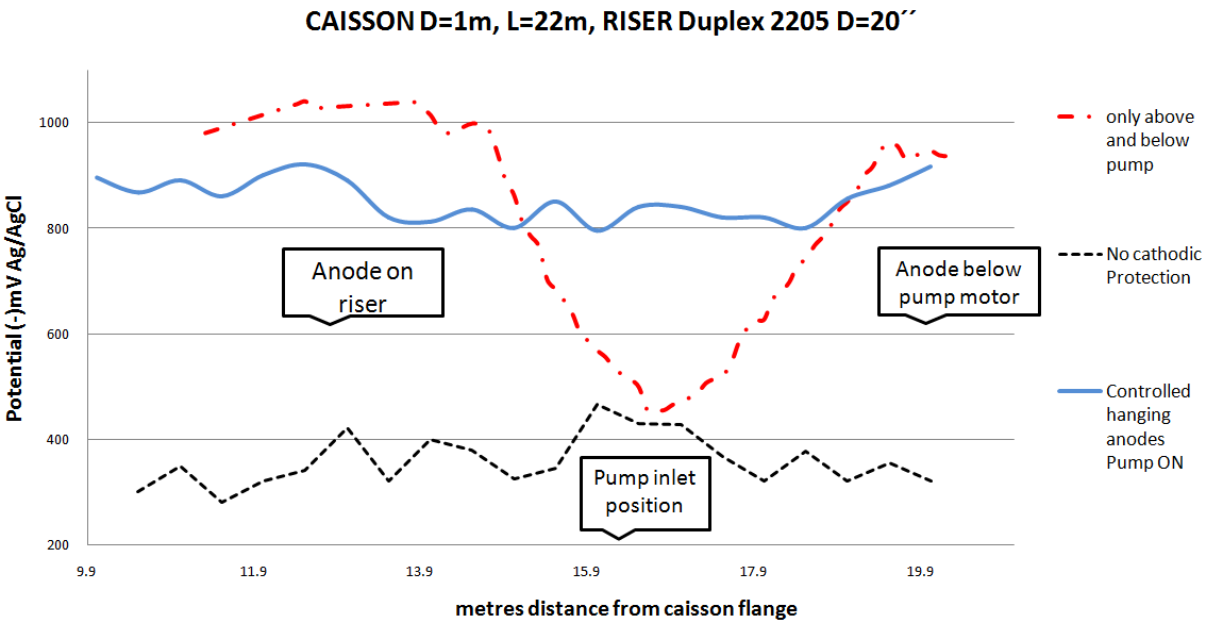


Figure 2: Potential measurements in the caisson; line-----: No cathodic protection. line.-.-.-.-.-: Anodes above and below the pump only. line_____:Anodes are hanging and evenly distributed over entire caisson length.

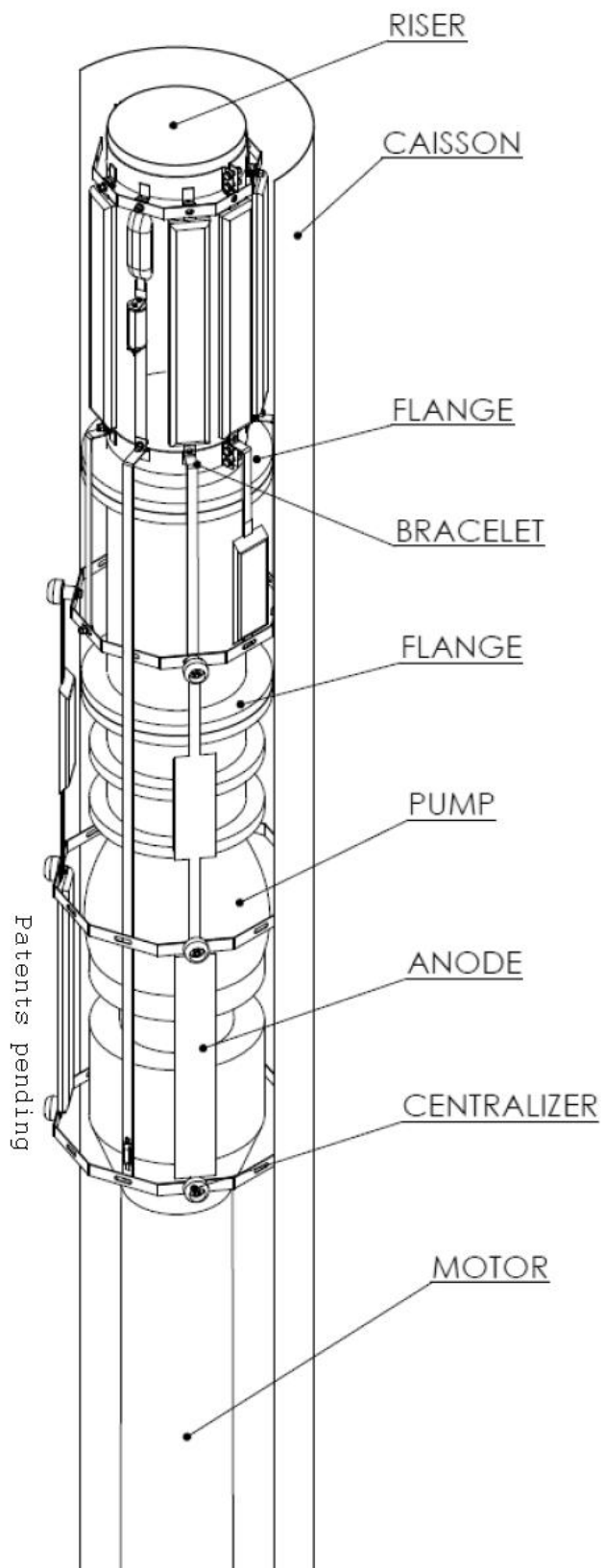


Figure 3: Hanging anode construction.

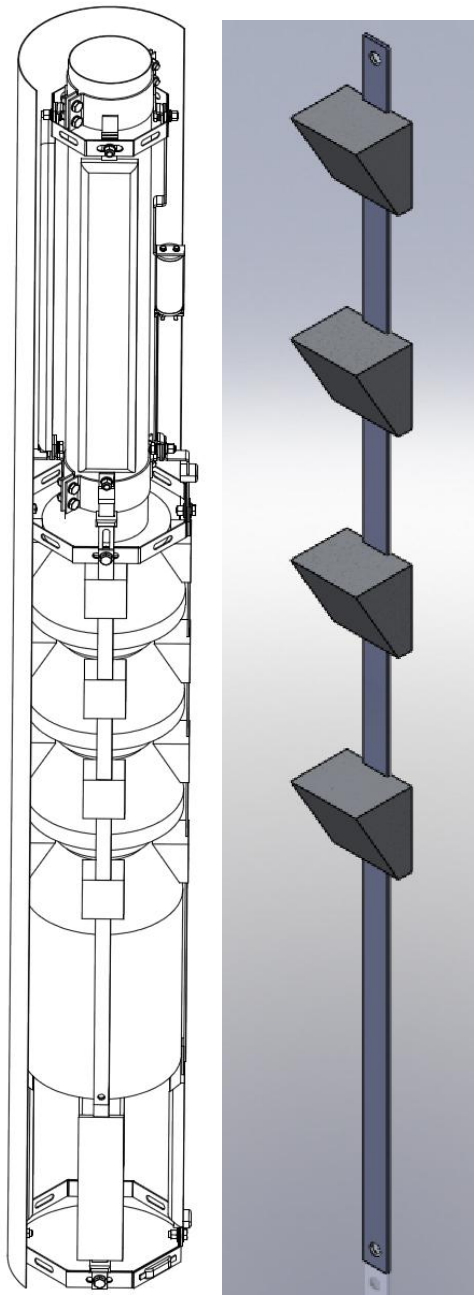


Figure 4: Hanging anode construction, tailor made anodes on diesel firewater pump.



Figure 5: Picture of hanging anode construction. Above: anodes and potential control unit are fixed on riser with bracelet construction. Three rows of anodes are hanging on this bracelet. Small anode left: Zinc-reference anode. Below: pump inlet. Ten sided stainless steel rings with Nylon centralizers keep the construction tight in the caisson.



Figure 6: Anodes hanging in the annulus. Note the robust but flexible construction with 10-sided stainless steel rings and Nylon centralizers.



Figure 7: Tank anodes below the pump motor. The stainless steel cylinder is the subsea enclosure with potential control unit. Behind the enclosure a Zinc-reference probe can be noted.