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Corrosion problems in seawater pump caissons. Practical solutions.

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ABSTRACT

After a subsea inspection on a relatively new platform in the North Sea substantial corrosion damage was revealed on the carbon steel seawater pump caissons. The subsequent offshore inspection utilizing a portable Ag/AgCl half cell revealed that the cathodic potential in the caisson was more positive than the free corrosion potential of carbon steel. Hence, the rapid corrosion failure of the caisson was related to galvanic interactions between the 6Mo stainless steel seawater pump and the carbon steel caisson.

A cathodic protection design based on galvanic anodes was performed according to NORSOK /1/. However, previous experience with similar problems had revealed that a design specifying the required anode alloy and amount of anode mass to achieve the requested lifetime would not solve the problem. The narrow annulus between the impeller section and the pump caisson internals introduces a significant larger potential drop than in the rest of the caisson. Hence, a computer model was established to verify that the anode current would pass the narrow annulus and polarize the damaged carbon steel impeller section sufficiently to avoid further corrosion development.

The final solution for distribution and type of galvanic anodes secured 10 years lifetime as requested by the client.

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INTRODUCTION

Through several years there has been severe corrosion damage on seawater pump caissons on offshore installations where the seawater pumps and the pump risers often are of noble alloys such as 6Mo, 25Cr super duplex stainless steel or Titanium while the pump caissons are of coated carbon steel. Even when a corrosion protection system is applied and designed as per recommended practices to cover the required amount of sacrificial anodes for the specified design life, seen severe corrosion damages in the pump impeller section has been observed.

This paper reviews the findings after an offshore inspection followed by a detailed cathodic protection design verified by SeaCorr computer modeling utilizing a boundary element method (BEM) to determine the required current densities and the potential drop properties in the most vulnerable areas. Finally a practical solution for anode distribution on the actual case is presented.

Case story

A subsea inspection on a relatively new platform located in the North Sea revealed substantial corrosion damage on a carbon steel seawater lift pump caisson. At approximately 13 meters depth divers found corrosion damages on one of the 2 caissons big enough to see directly into the stainless steel seawater pump, only 4 years after commissioning. The visible corrosion damage covered an area of approximately 10 x 70cm. The detected corrosion damage seen from outside of the caisson are shown in figures 1 and 2, while a sketch showing the extent of the damage is shown in figure 3.

After the sub sea inspection it turned out somewhat unclear whether any cathodic protection was installed to prevent corrosion. Hence, a top side inspection was conducted utilizing a portable Ag/AgCl half cell that was lowered through the caissons and the potential profile was logged with a multi meter, meter by meter from the seawater surface. The pump was stopped while conducting this inspection. The potential profile from the seawater surface and down to approximately 10 meters below the pump is showed in figure 4.

In figure 4 the 0-point on the Y-axis is the seawater surface. The final recorded potential value is at 30 meters, which is approximately 10 meters below the stainless steel pump. As one can see in figure 4 the potential down to 10 meters depth varies between 250 to 150 mV (Ag/AgCl). When reaching 12-16 meters one can see that the potential goes more negative in large steps per meter. It is obvious that no cathodic protection system is installed to prevent corrosion on the caisson, and further the recorded potential values proves that there was full galvanic effect between the stainless steel seawater pump and the carbon steel caisson. In addition it was found that the corroded area was in the section with a narrow annulus by the impeller section on the pump. This narrow annulus is also known to create a large potential drop down the caisson length due to the decreased cross section. This is also observed in figure 4.

A cathodic protection design was conducted to prevent from further corrosion damage. A lifetime of 6 years minimum but 10 years preferably was requested by the client to meet the planned schedule for pulling the pumps for inspection. However, as similar situations also have been seen on stainless steel pump and carbon steel combination even with cathodic protection installed, computer modeling with SeaCorr software utilizing Boundary Element Method (BEM) was used to verify the design calculations, and most important to verify that sufficient current was transported though the narrow annulus on the impeller section to polarize sufficient enough the prevent against corrosion. The cathodic protection design was based on Norsok /1/, but as corrosion damage was already present, the recommended coating breakdown factors from /1/ were increased. The coating breakdown factors used in the design are listed in table 1.

Three main cases were studied in order to get the most efficient solution:

1. No coated areas on the seawater pump
2. Coated pump riser and impeller section with no coating on the strainer
3. Coated pump riser, impeller section and strainer

Note:

1) On point no 2 above it was decided to evaluate to coat two (of a total of 15) pump riser sections covering 4,5 meters above the impeller section with the narrow annulus. The installed cathodic protection system would polarize to a safe potential below -800 mV (Ag/AgCl). Hence, coating two riser sections was considered to be sufficient to avoid galvanic corrosion in the vicinity of the already damaged area. Furthermore it was considered that current distribution for sufficient polarizing would not be a problem above this area due to the larger annulus between the riser and the internals of the caisson.
2) In several similar cases significantly larger current density values than 75-100 mA/m2 as normally recommended for cathodic protection of carbon steel are observed in the close vicinity of the impeller section, most likely caused by high seawater velocity affecting the stability of calcareous deposits which again will affect the required current density for sufficient polarization. Hence, the strainer area was multiplied with a factor of 3 to allow for a current density in order of 300mA/m^2 for sufficient polarization in the close vicinity of the strainer. It is however assumed that the high current density values seen in similar cases would drop to more normal values after some time as calcareous deposits is expected to build up. Some uncertainties to this should be paid attention as these layers will be inflected by the flow conditions.

Based on previous experience galvanic anodes on the pump risers only would not be sufficient to protect the caissons in the impeller sections and areas below as the narrow annulus would introduce a too large potential drop. The inspection and modeling results from previous experiences are shown in figures 5 and 6. Hence, all modeling was performed based on anodes both on the pump risers and the impeller section. In addition two scenarios were studied

1. Optimized anode number to achieve minimum of 6 years as requested
2. Optimized lifetime evaluations to achieve 10 years lifetime of the galvanic anodes, as this is assumed to be the remaining field lifetime. This would be limited by the available space for anodes in the narrow annulus between the impeller section and caisson.

Model basis:

The boundary element model is based on the true geometries of all components; seawater caisson, seawater pump and anode geometry. The anode geometry is limited by the available cross section area in the smallest annulus in the pump impeller section. The boundary element method will then from the prepared model geometry and boundary conditions calculate the potential and current density distribution.

All modeling results below are based on the following:

- Flush mounted Al-Zn-In galvanic anodes 10 kg`s each which was found as a sufficient dimensions related to the available annulus
- Potential range from 0 to -900 mV (Ag/AgCl) for the 6Mo pump
- Potential range from -600 to -900 mV (Ag/AgCl) for the carbon steel seawater caissons

A figure showing the cathodic protection level in case 1 above, with no coating on the pump, is shown in figure 7. Case 2 with coated pump riser only and case 3 with coated pump riser and strainer are showed in figures 8 and 9 respectively. Note that the anodes on the impeller section can be seen on the figures, but the mesh is only shown to be able to spot the impeller section area. Figures 7-9 reflects simulations based on a total anode weight to secure 10 years lifetime.

In figure 7, with the entire pump uncoated it can be seen that the carbon steel caisson is sufficiently protected around-, and above the impeller section. However, it is shown that the potential drops quickly below the impeller section to levels in order of -700 mV (Ag/AgCl). On the first pump riser section above the impeller section the potential is only in the order of -850 to -950 (Ag/AgCl) caused by the large current drain to the uncoated strainer which represent a significant part of the area.

In figure 8, with the pump risers coated and bare strainer it is clear to see the improvements in protection level above the impeller section while also the caisson area surrounding the strainer is marginally protected at approximately -800 mV (Ag/AgCl), but then rapidly decrease to in the order of -700 to -750 mV (Ag/AgCl) just below the strainer area.

In figure 9, with all stainless steel areas coated, it is clear to see that a larger portion of the caisson is protected below the trainer section below the impeller section.

At the final stage of the project it was decided not to coat the strainer as the uncertainties with regards to the quality of the coating on such perforated components, there would be a risk of coating flakes going through the seawater system. Hence, the case 2 above with coated pump risers and bare strainer was chosen as the final solution. In addition, as assumed early in the project phase it would not have been possible to obtain sufficient protection in the already damaged caisson areas without continuous galvanic anodes covering the entire length of the impeller section.

Discussion

The potential profile recorded above 10 meters on the seawater caisson is considered to reflect the free potential of 6Mo in seawater. When approaching the corroded area it is clear to see that the potential rapidly shifts to negative values that are caused by bare exposed carbon steel. The recorded potentials below 12 meters to the bottom end of the pump are evaluated to be a mixed potential between carbon steel and 6Mo stainless steel. The main purpose with the inspection was to prove that no cathodic protection system was protecting the internals of the seawater caissons and that the rapid corrosion was caused by galvanic interactions between the carbon steel caissons and the seawater pumps. Furthermore the inspection is once more revealing the large potential drop in the narrow annulus that will be critical of any CP design in cases like this actual case story.

From the pictures taken of the corrosion damage, (figures 1-3) the damage seems to occur in the longitudinal direction rather than around the circumference. This might indicate that the damage occurred on the pipe longitudinal weld, and that scratches have been introduced on the coating when the pump was installed for commissioning and after an inspection where the pump had been withdrawn.

Conclusions

- For this actual case continuous galvanic anodes on the impeller house were necessary to obtain protection against galvanic corrosion
- The strainer was decided not to be coated as the coating quality and durability was considered to be low.
- A solution with 8 of each 10 kgs anodes and 2 of each 10 kgs anodes on the impeller house and pump riser sections respectively were chosen as the most suitable solution.
- The recommended solution would stop galvanic corrosion on the caissons, but as the potential close to the strainer only would be -700 to -750 mV (Ag/AgCl) a corrosion rate in order of 50µm/year could be expected on bare carbon steel around the strainer (figure 8).
- The ongoing problem with galvanic corrosion issues on seawater pump caissons continues despite that a number of recommendations have been submitted to ship yards designing and building off shore rigs.
- A traditional cathodic protection design based on common recommended practices does not solve the corrosion problem as the problem area on the lower impeller/motor section with decreased cross section area and limited anode space is not covered by a standard CP design.
- Computer modeling is a useful tool for solving the problems in such cases and for optimizing cathodic protection designs for such problem areas. It is however, a presumption that the simulations are based on validated data ensuring correct results.

References:
/1/ NOSOK M503, rev 2 Cathodic Protection, September 1997.

Figure 1 Corroded area after cleaning off the shells and growth

Figure 2 Measured extent of the corroded area

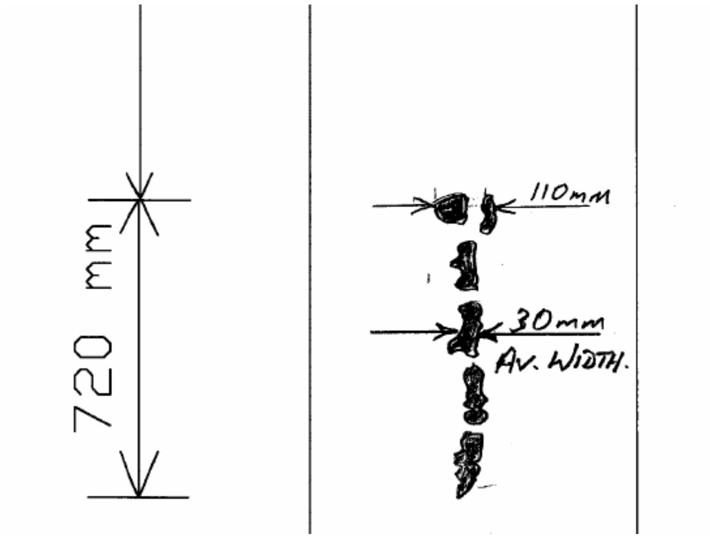

Figure 3 Sketch of the extent of the corrosion damages.

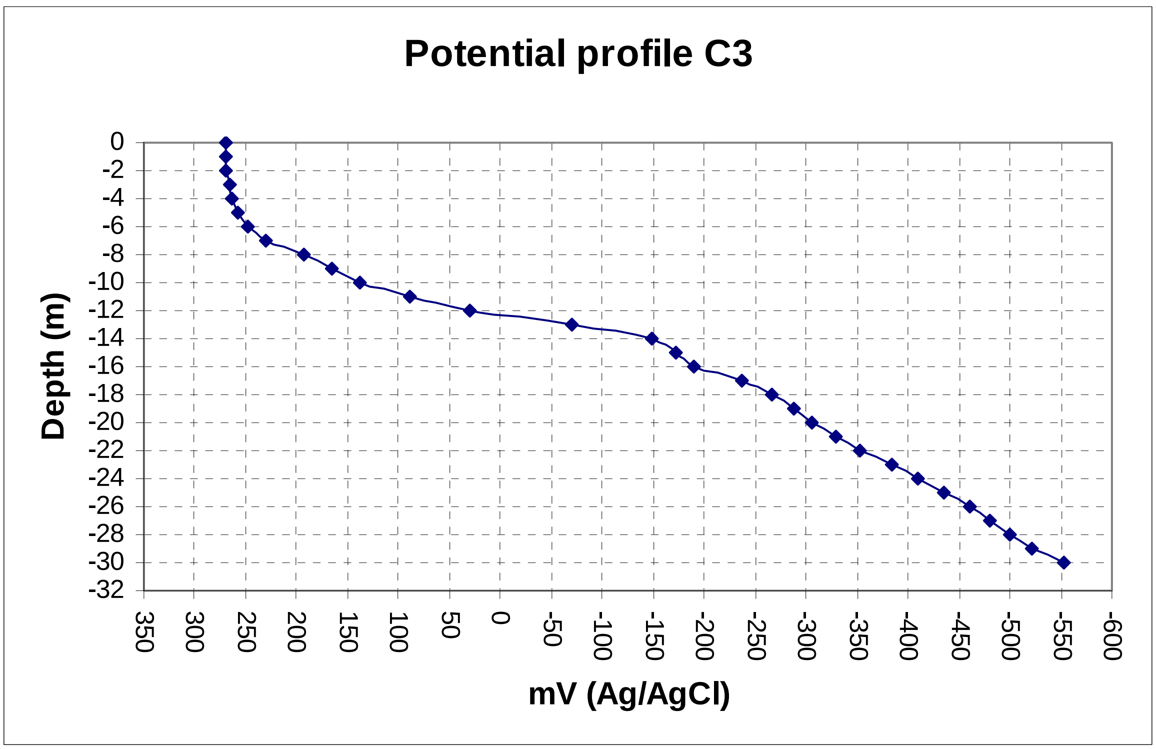

Figure 4 Recorded potential profile in the seawater caisson.

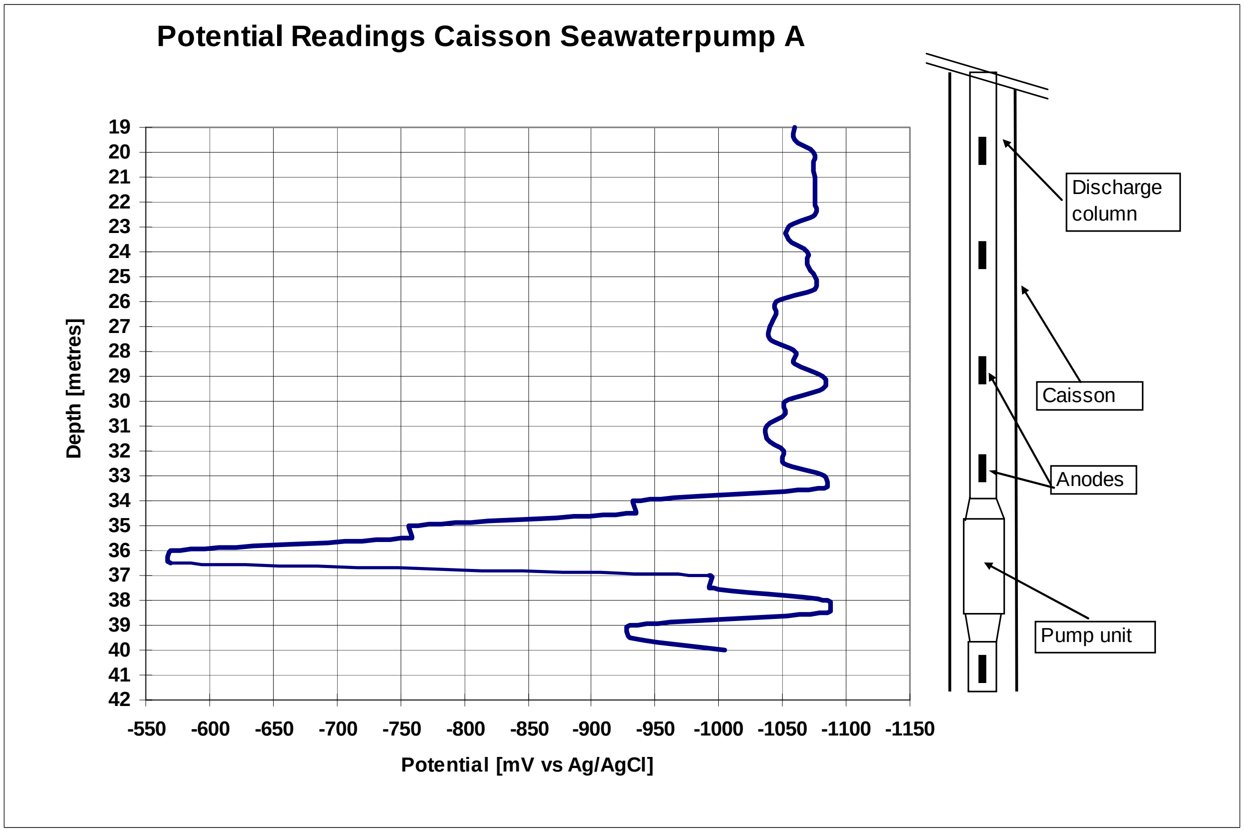

Figure 5 Potential drop recordings from survey with a portable Ag/AgCl half cell

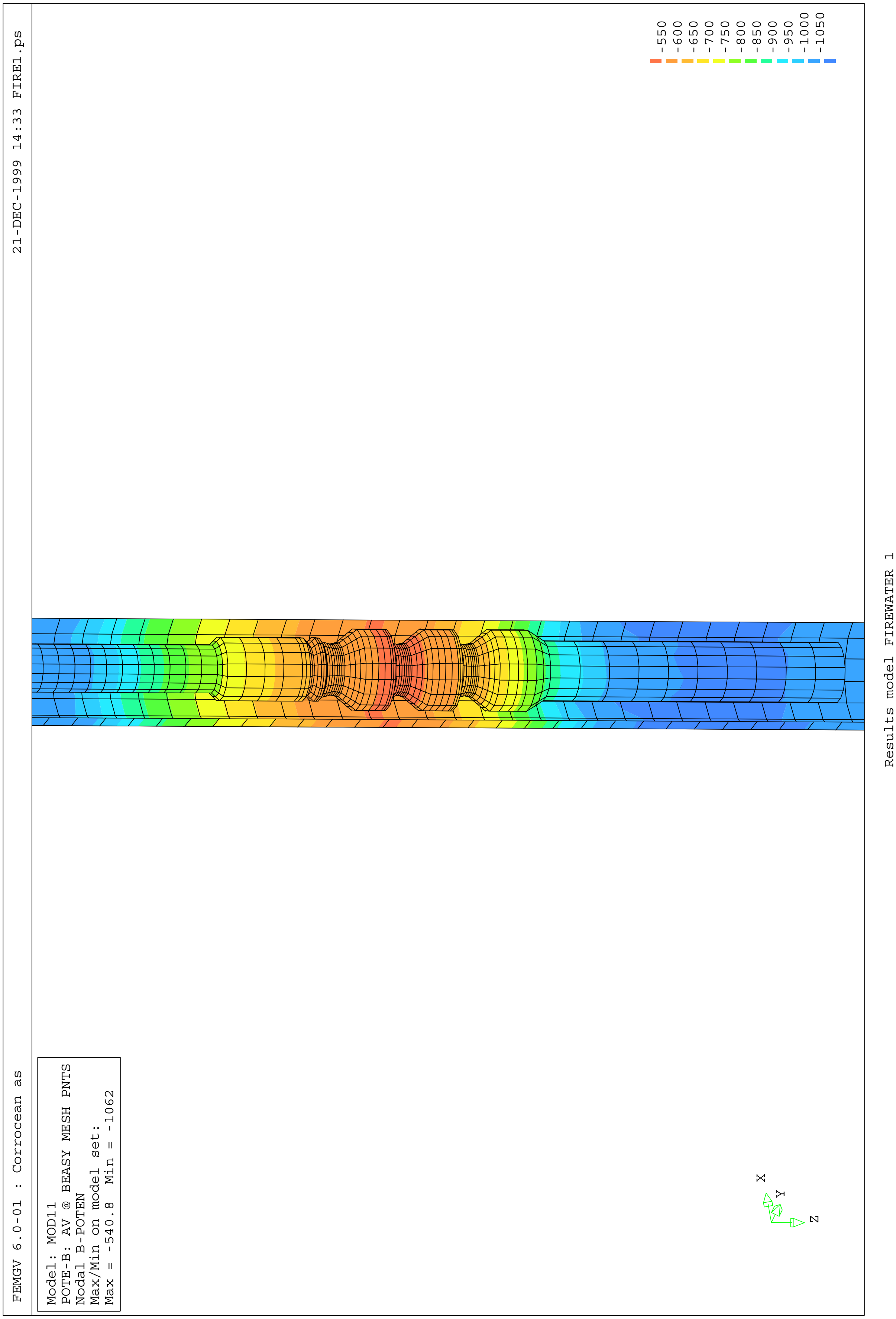

Figure 6 SeaCorr computer simulation model of the actual situation inspected in figure 5

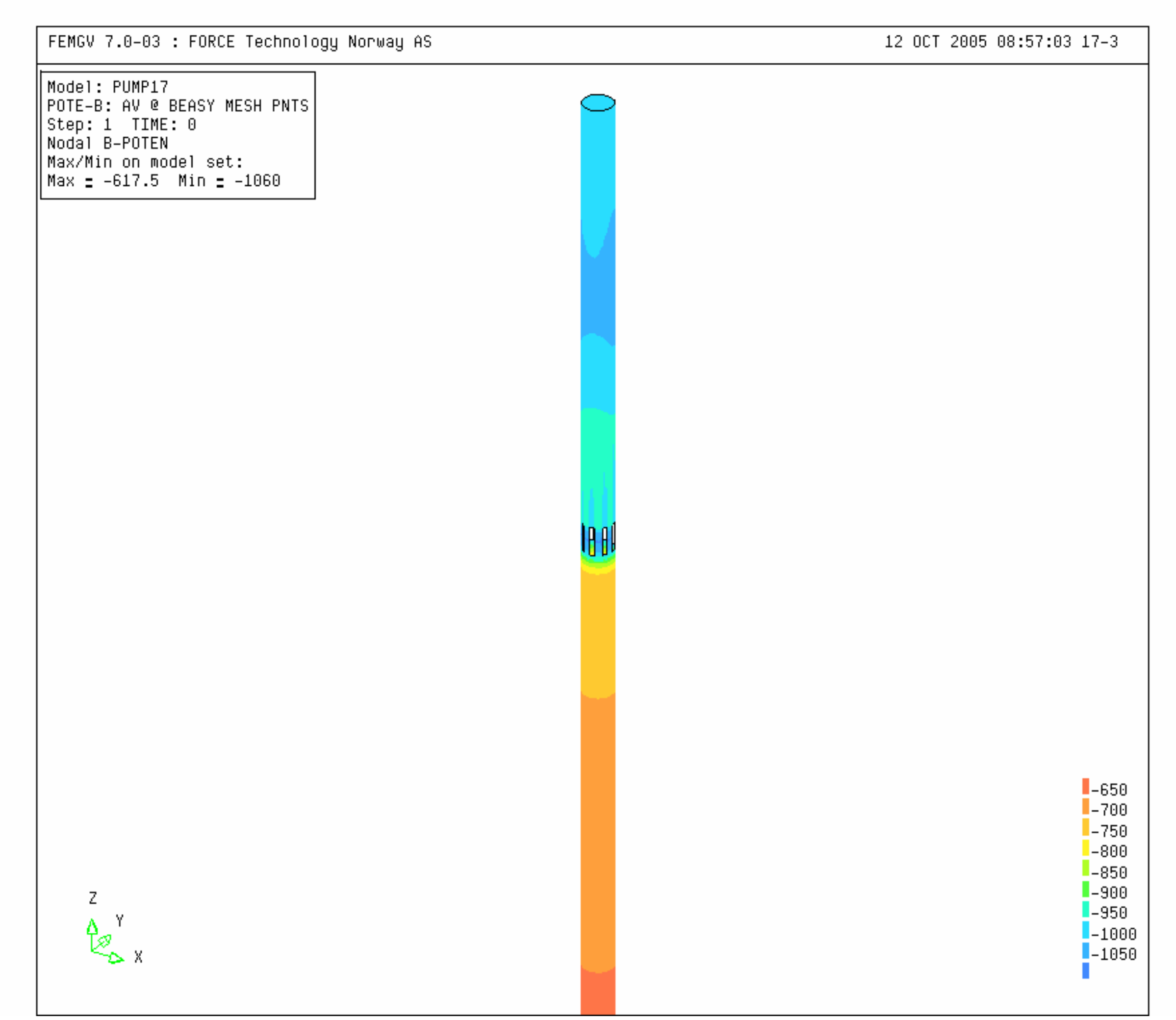

Figure 7 Case 1-Potential profile on the seawater caisson with galvanic anodes on pump riser and impeller section without any coating on the lift pump sections.

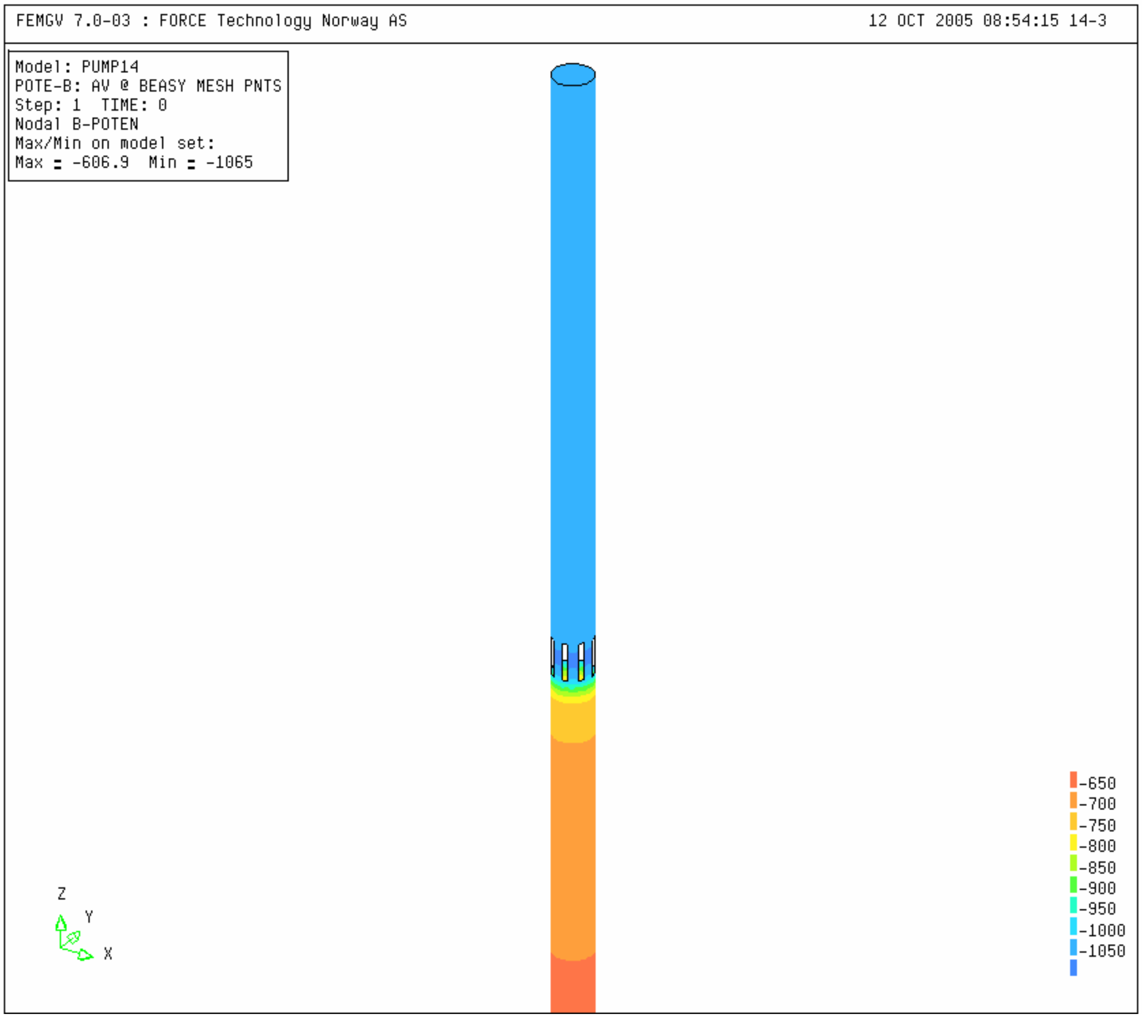

Figure 8 Case 2- Potential profile on the seawater caisson with galvanic anodes on pump riser and impeller section with coated pump riser and strainer left bare.

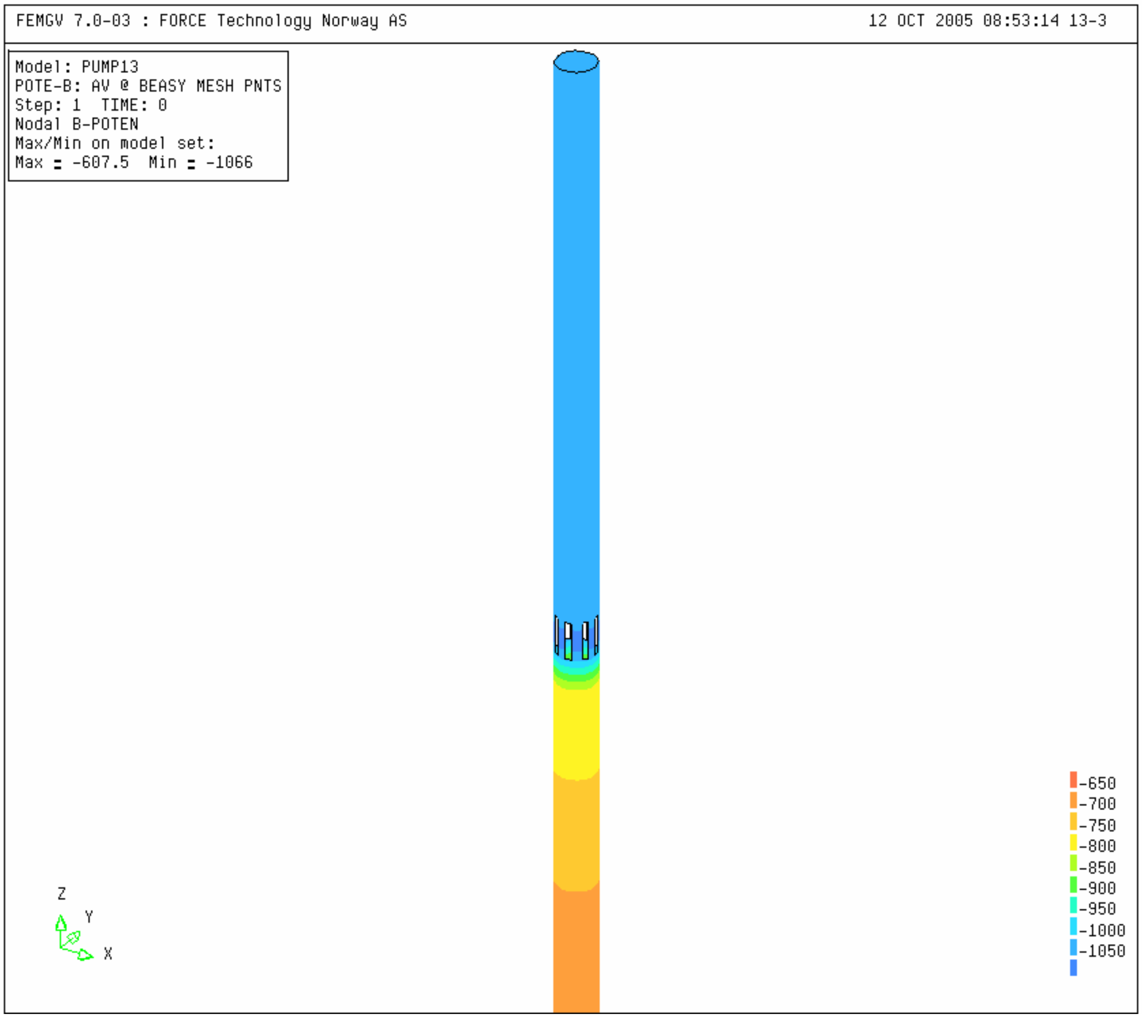

Figure 9 Case 3- Potential profile on the pump caisson with galvanic anodes on the pump riser and impeller section with coated pump riser and strainer

Table 1 Coating breakdown factors

	Initial	Mean	Final
Upper caisson area	0,16	0,19	0,22
Lower caisson area	0,05	0,07	0,10
Coated pump string	0,02	0,04	0,06
Coated Strainer 1)	0,27	0,29	0,31

1) It is considered as difficult to obtain a sufficient coating on the strainer due to all perforations and risk of coating damage. Hence, a coating degree of 75% is considered as sufficient for the design calculations.