A new corrosion probe

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Summary

To detect AC corrosion the local corrosion rate must be monitored. This can be done by excavating test coupons. A newly developed probe, the LC probe, indicates when the most severe attack reaches a critical depth. The probe has been evaluated in laboratory and in accordance with other investigations it has been found that the geometry of the defect is vital for the rate of pitting corrosion taking place at the edge of the defect. All kind of defects are present in the field. A probe must therefore warn if the stray current situation can create deep attacks in critical defects. LC probes have a spread resistance which is 30 % lower than that of circular defects giving a safety marginal.

1. Introduction

Corrosion attacks caused by stray current often results in local attacks. ER probes give limited information on the rate of pitting corrosion. In many cases test coupons are needed for this evaluation. To install, excavate and evaluate test coupons is time consuming and expensive. As an alternative SCS Engineering has developed a new corrosion probe called LC probe (local corrosion detection probe) which is protected by a patent. The probe can be used in different environments and applications, one is corrosion control of pipelines. The probe gives an early warning if deep pits are being formed due to stray current interference.

Field tests are to be performed on the Swedish gas net, but until now results are only available from laboratory tests. The probe as well as some of the tests having been performed is described in this paper.

2. Technical description

Investigations concerning AC corrosion are being performed in most countries. In Sweden we have a project soon to be finished where test coupons have been exposed in laboratory for 1,35 years under different conditions (1). Below is the results from exposure in clay where the CP level has been –1100 mV CSE and the AC level kept between 0 and 30 V.

The results are based on triplicate samples. As can be clearly seen, the maximum pitting corrosion rates are a factor 5 to 10 greater than the corrosion evaluated as uniform corrosion (mass loss). It is therefore of vital interest to monitor the local corrosion rate.

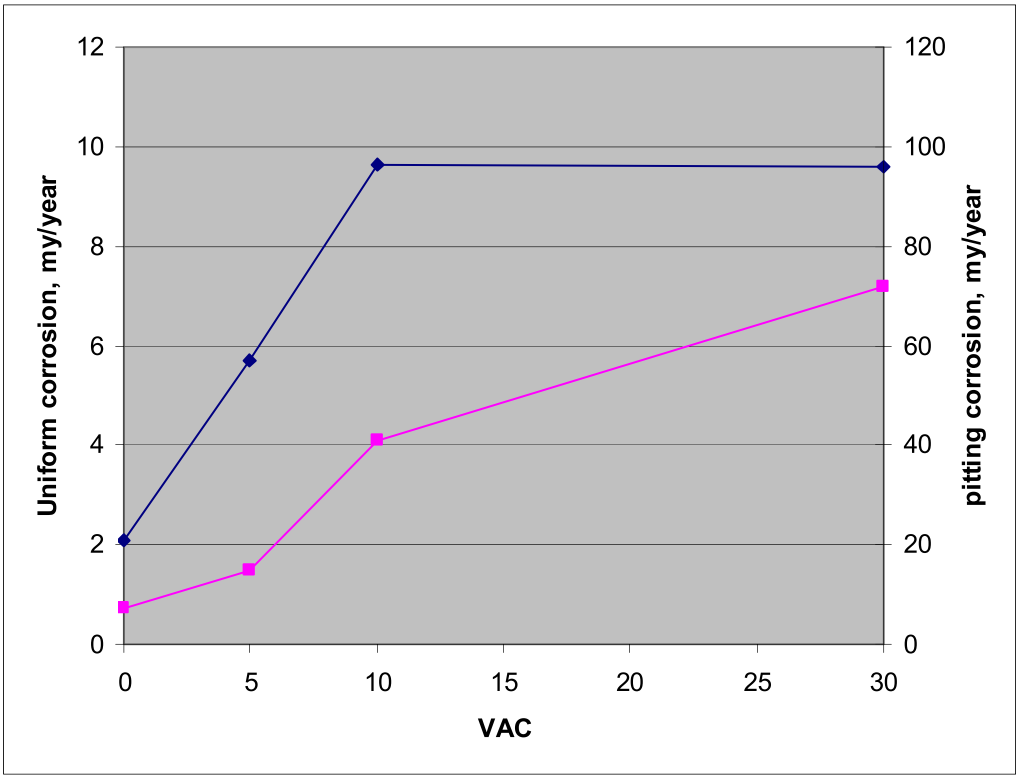

Figure 1. Uniform and pitting corrosion rates in clay with a CP level of –1100 mV and different AC voltages (uniform corrosion = blue line, pitting corrosion = red line).

The LC probe can be used as a test coupon for regular measurements but its primary purpose is to give a warning when the deepest pit reaches a predestinated value.

The probe, shown in figure 2, 3 and 4, consists of a steel tube connected to a flexible copper tube. Both tubes are covered with a shrinkage tube except for the defect on the steel tube, see figure 4. The copper tube is fitted into a junction box. To the same box a valve and a manometer is connected enabling to pressurise the copper/steel tube and monitor the pressure. This packaged is placed within a plastic container which is mounted within the ordinary test post for CP control. Electrical contact with the pipeline is achieved through a cable to the measurement socket. In this way the probe is exposed to the same interference as coating defects on the pipeline itself, as in the case of test coupons.

When the deepest pit penetrates the wall of the exposed steel surface the pressure falls and this is indicated on the manometer. The size of the defect as well as the wall thickness can be varied. The principle is very simple but it saves man hours and increases pipeline integrity.

Figure 2. LC probe

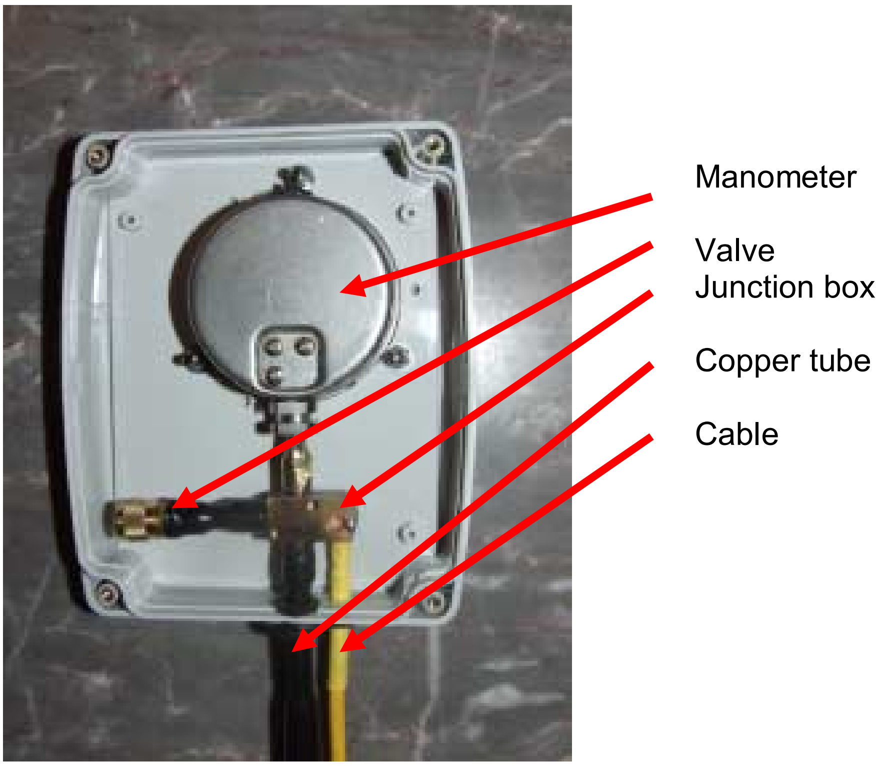

Figure 3. Junction box with attached copper tube, valve, manometer and cable.

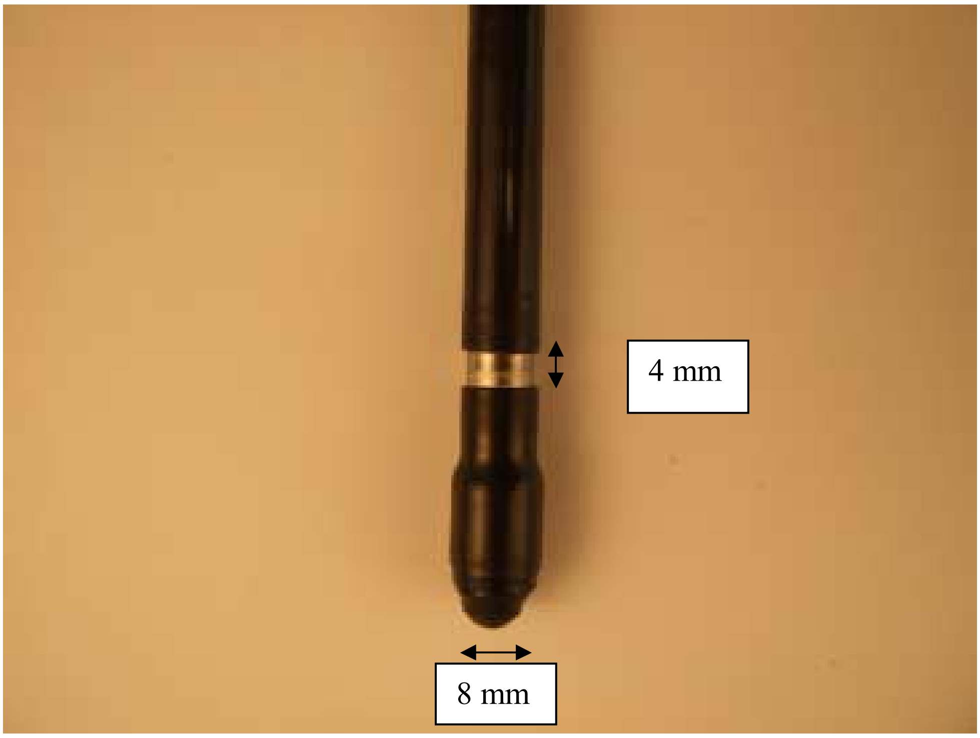

Figure 4. Defect. In this case 1 cm^2.

3. Performed tests

The aim of these tests was not to investigate AC or DC corrosion phenomena. Instead we wanted to see how the probe behaved under different conditions as compared to normal test coupons.

3.1. Exposure to DC stray current

The probe was immersed in tap water with a resistivity of 50 Ωm and exposed to an anodic DC current of 2 mA, corresponding to a current density of 20 A/m^2. 1 A/m^2 results theoretically in a corrosion rate of 0,9 mm/year. In this case the expected corrosion rate was therefore 18 mm/year. With a wall thickness of 1 mm, all exposed steel in the defect will be consumed after 20,2 days. The pressure dropped after 16,5 days which means that the attack was close to uniform. The highest corrosion rate was registered 0,5 – 1,0 mm from the edge of the coating. Some corrosion had also taken place under the coating itself, see figure 5.

Figure 5. Probe after 16,5 days of exposure to an anodic DC current density of 20 A/m^2.

Initially the highest current density is anticipated at the edge of the coating. The area exposed to the highest current density (corrosion rate) will alter according to figure 6, resulting in a penetration at some distance from the coating edge.

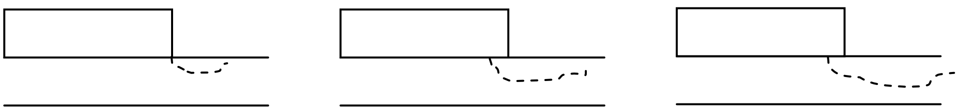

Figure 6. Principal development of corrosion attack.

3.2 Exposure to AC stray current and cp

The probe was immersed in tap water and given CP from a large zinc anode. An AC current (60 A/m^2) was super imposed to the DC current. After 5 months the test was interrupted. The exposed surface before and after removal of coating and corrosion products are presented in figure 7 and 8.

Figure 7. Test prope after exposure for 60 A/m^2 AC and cp from a zinc anode.

Figure 8. Test prope after removal of corrosion products.

As can be seen from figure 7, severe corrosion has taken place at the edge of the defect and the remaining surface is close to unaffected. High corrosion rates at edges have been reported earlier and been explained by higher DC current densities at edges (2).

How the current density depends on the geometry of the defect has been calculated in COMSOL for the cases shown in figure 9. The model was based on a defect size of 1 cm^2, the resistivity 10 Ωm and the DC voltages 10 V.

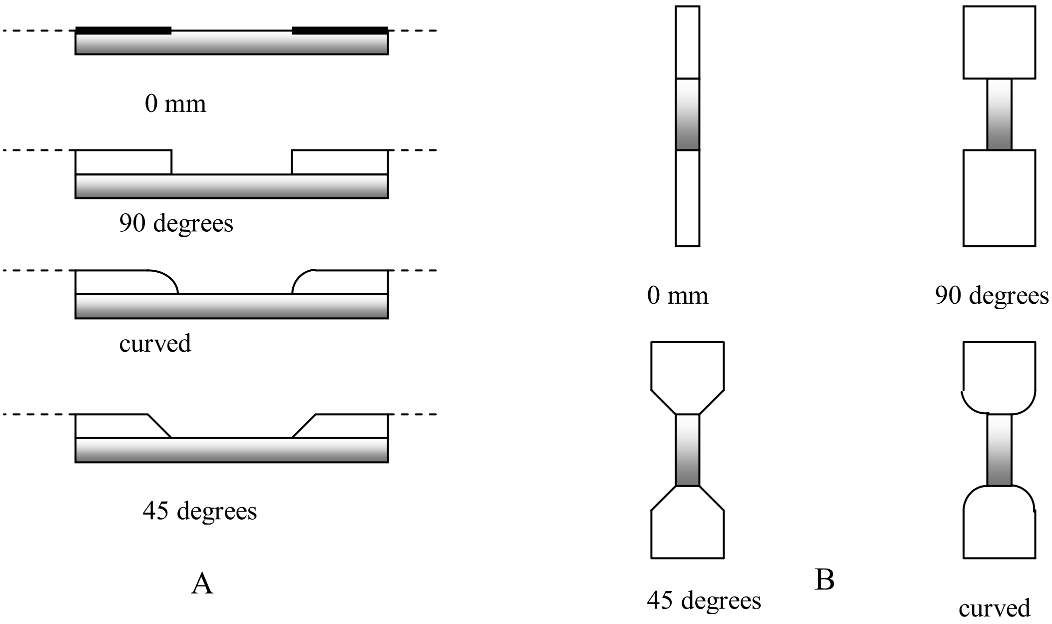

Figure 9. Defect geometries used in the model. A circular defect and B cylindric.

At a size of 1 cm^2 the spread resistance for a defect is 30 % lower for a cylindric defect as compared to a circular defect. The calculations show bigger differences in current densities between the two type of defects but this is due to different models being used. For the circular defect we have used an isolated plane giving a half spherical field. In the cylindric case the field is spherical. The variations in current density over the defects are however not influenced by this. The results are presented in figure 10 – 15.

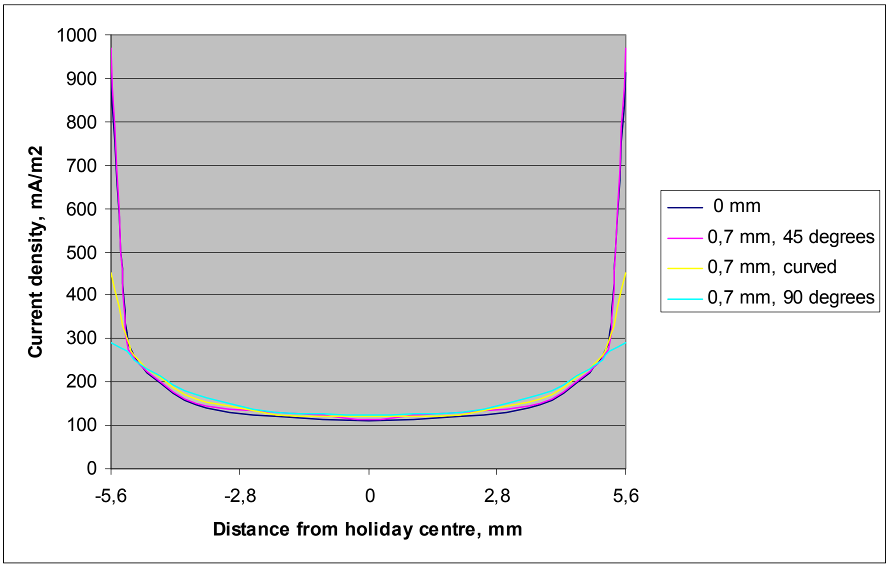

Figure 10. Calculated current distribution for a circular defect, 1 cm^2, with coating thickness of 0 mm as well as 0,7 mm and with different geometries.

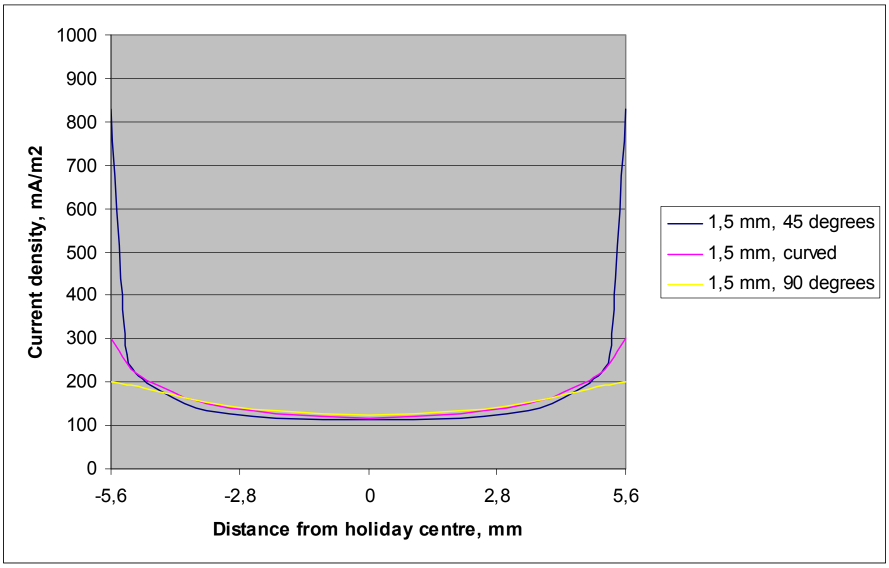

Figure 11. Calculated current distribution for a circular defect, 1 cm^2, with coating thickness of 1,5 mm and different geometries.

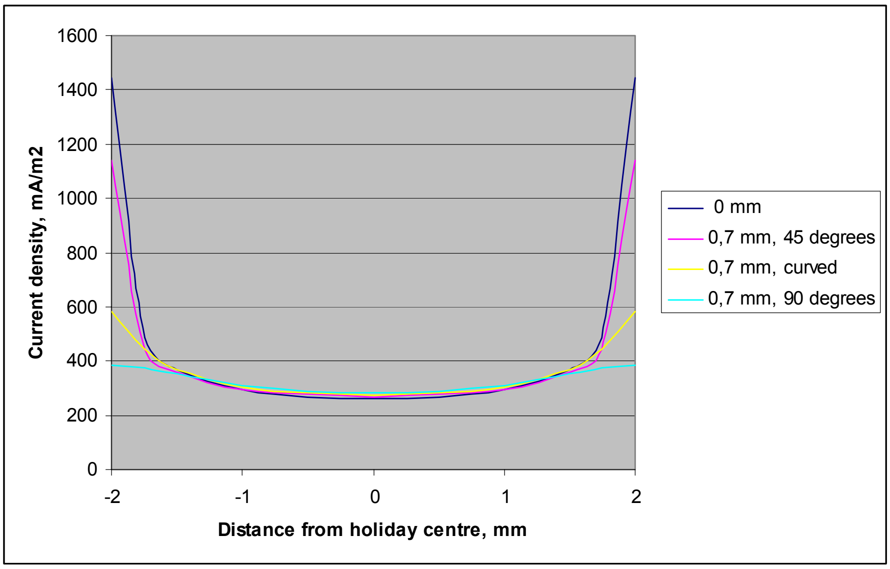

Figure 12. Calculated current distribution for a cylindric defect, 1 cm^2, with coating thickness of 0 mm as well as 0,7 mm and with different geometries.

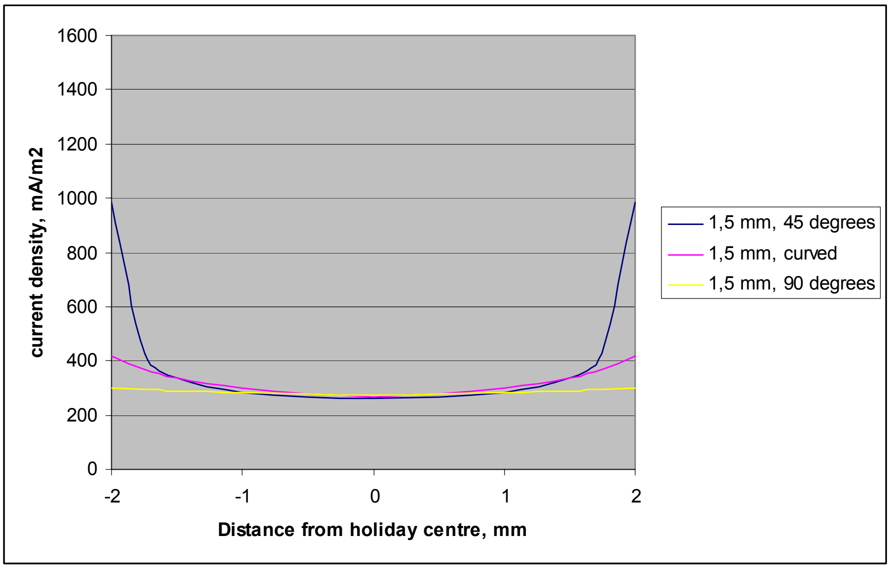

Figure 13. Calculated current distribution for a cylindric defect, 1 cm^2, with coating thickness of 1,5 mm and different geometries.

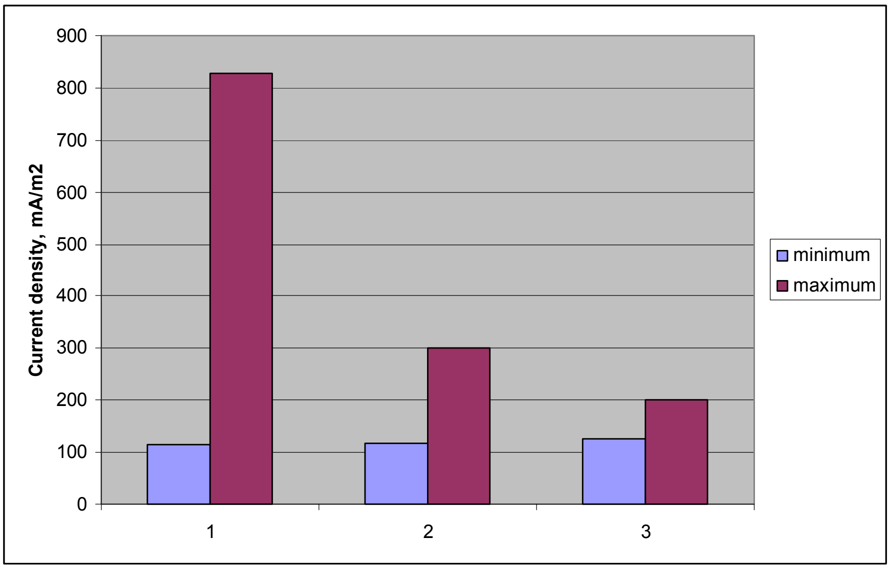

Figure 14. Maximum and minimum current density on circular defects with different geometries. Coating thickness 1,5 mm. (1= 45 degrees, 2= curved, 3=90 degrees).

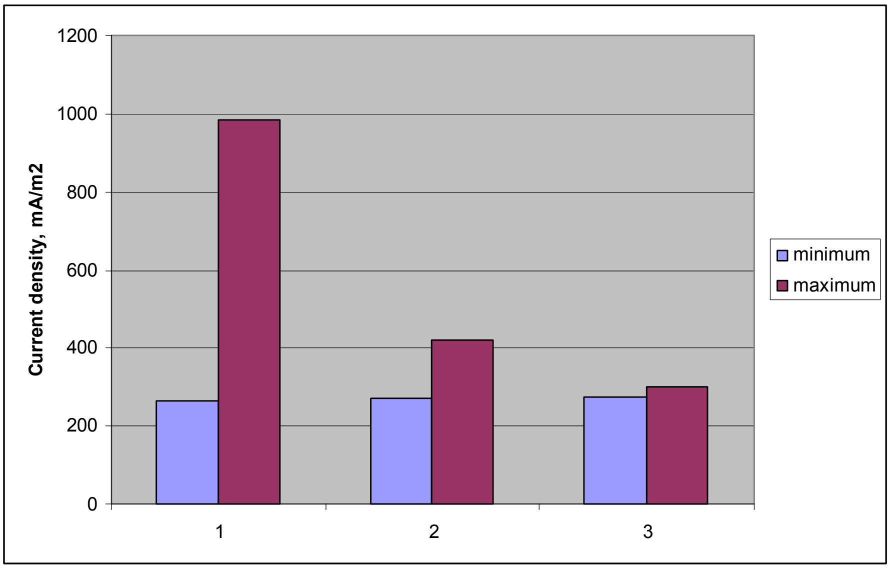

Figure 15. Maximum and minimum current density on cylindric defects with different geometries. Coating thickness 1,5 mm. (1= 45 degrees, 2= curved, 3=90 degrees).

The results show that the maximum current density at the edge is of the same magnitude for the two geometries “zero coating thickness” and “45 degrees”.

In our exposure test, the coating thickness was 0,7 mm and the coating edge “90 degrees”. Figure 12 shows that the variation in current density between the defect centre and the edge is not big, 300 as compared to 400 mA/m^2. Even though the differences in corrosion attack is dramatic between the edge and the centre. This indicates that the DC current density is not the whole explaination. As can be seen in figure 16, the scale is cracked in the vicinity of the edge, probably due to internal stresses. This may cause more current to be transfered in a resistive and less capacitive way in this cracked area.

Figure 16. Cracks in the scale, in the area of severe corrosion.

4. Discussion

What is important for the owner of a pipeline being exposed to AC stray currents?

To measure current densities and/or voltages is only a way to estimate the corrosion risk. Evaluation of the uniform corrosion rate is not enough. To get an early warning if severe pitting corrosion is taking place is however of great interest. This can be accomplished with test coupons. The same information can also be collected using a LC probe but in a more economical way and the warning is received without delay.

It is quite clear that the geometry of the defect has a strong impact on the magnitude of local corrosion taking place. In practice we have to calculate with all kind of defects possibly being present. A probe must therefore be designed in that way that it indicates if the premises (DC and AC level, soil composition.....) can create attacks in critical defects.

The defect of the LC probe has a 30 % lower spread resistance than that of a test coupon which gives additional safety. If the edge of the coating is cut in a 45 degrees angle the local current density is greatly increased as compared to a straight cut. On the other hand a straight cut (90 degrees) may results in cracks in the scale which indirectly increases the resistive current density. This dilemma can be dealt with by having two different defects on the same probe, see figure 17.

Figure 17. LC probe with 2 different defects.

5. Conclusions

The performed investigation permits the following conclusions:

- To detect AC corrosion the local corrosion rate must be monitored.
- The local corrosion rate can be evaluated by excavating test coupons but LC probes gives an economic benefit and results are received without delay.
- The geometry of the defect is vital for the rate of pitting corrosion taking place at the edge of the defect.
- Probes must warn if the stray current situation can create deep attacks in critical defects.
- LC probes have a spread resistance which is 30 % lower than that of circular defects giving a safety marginal.

6. References

1. Work in progress at Swerea/KIMAB, EnergoRetea, Midroc Engineering and EON.
2. Buchler, M & Schöneich, H:G: The effect of ac interference over time on the corrosion of cathodically protected pipelines. CEOCOR. 2009.