Accelerated Corrosion Under the Combined Influence of SRB and Anodic Interference - a Case Study

by

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During the construction of a new water pipeline, a section of the pipeline was subject to anodic interference from a nearby pipeline under cathodic protection which it crossed.

When the new pipeline was being cleaned for pressure testing, it was discovered that a scour fitting had been perforated at a number of locations. It was suspected that the corrosion had occurred at defects in the epoxy lining, as this section of pipe was in a low area and was filled with mud. Once the fitting had been cut out and removed for inspection, it was found that the corrosion had proceeded from the outside at defects in the external coating.

This paper presents the findings of the investigation together with the monitoring records during construction which highlight the importance of implementing corrosion mitigation measures from the outset during pipeline construction

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1. INTRODUCTION

As investigation was undertaken to determine the cause of holes in a scour sump Tee on an epoxy lined and polyurethane coated water pipeline which occured during construction, prior to commissioning.

The holes were discovered during internal cleaning of the pipe prior to pressure testing. No external coating defects had been identified at this location during the post-construction DCVG survey. Apparently the Tee had not been backfilled at the time of the survey and therefore was not surveyed. The invert of the Tee was sitting in wet spoil which had collected at the low point. The internal of the pipe had also been partially filled with mud which had washed in during construction. Initial reports from site staff suggested that the corrosion had occurred at points of damage to the eppoxy lining.

This scour was close to the crossing of a foreign cathodically protected pipeline.

The Tee was cut out and removed for inspection. The corrosion morphology was visually examined and samples of corrosion products were taken for bacterial and chemical analysis.

The potential of the pipeline at the Tee was measured prior to it being removed, and the construction monitoring records were scrutinised to determine the history of pipe/soil potentials for the pipeline in the area.

The construction drawings indicated that the wall thickness of the sump was 9mm, and that it had been installed some 14 months previously.

2. VISUAL INSPECTION

Once the pipe section had been removed and cleaned, it was apparent that the pipe had corroded from the outside at locations of external coating defects. The corrosion had perforated the pipe and in some cases then continued radially, developing a cylindrical hole. There were sites of internal corrosion at coating defects on the welds, but these had not caused any significant metal loss.

The morphology of the corrosion was typical of bacterial corropsion in that the corrosion pits were filled with black corrosion product which could easily be removed, leaving a shiny steel surface exposed. The base of the pits also had a characteristic scalloped appearance. This black corrosion product rapidly oxidised to the familiar red-brown hydrated oxides on exposure to air. These characteristics are peculiar to sulphate reducing bacteria (SRB) corrosion.

Alternative corrosion mechanisms would be expected to show the following characteristics:

- Soil corrosion generally results in red-brown corrosion products which are not easily removed, and do not expose a shiny steel surface when removed.
- Stray current corrosion from DC interference carries the corrosion product away from the surface, leaving a clean hole in the steel with little or no corrosion product

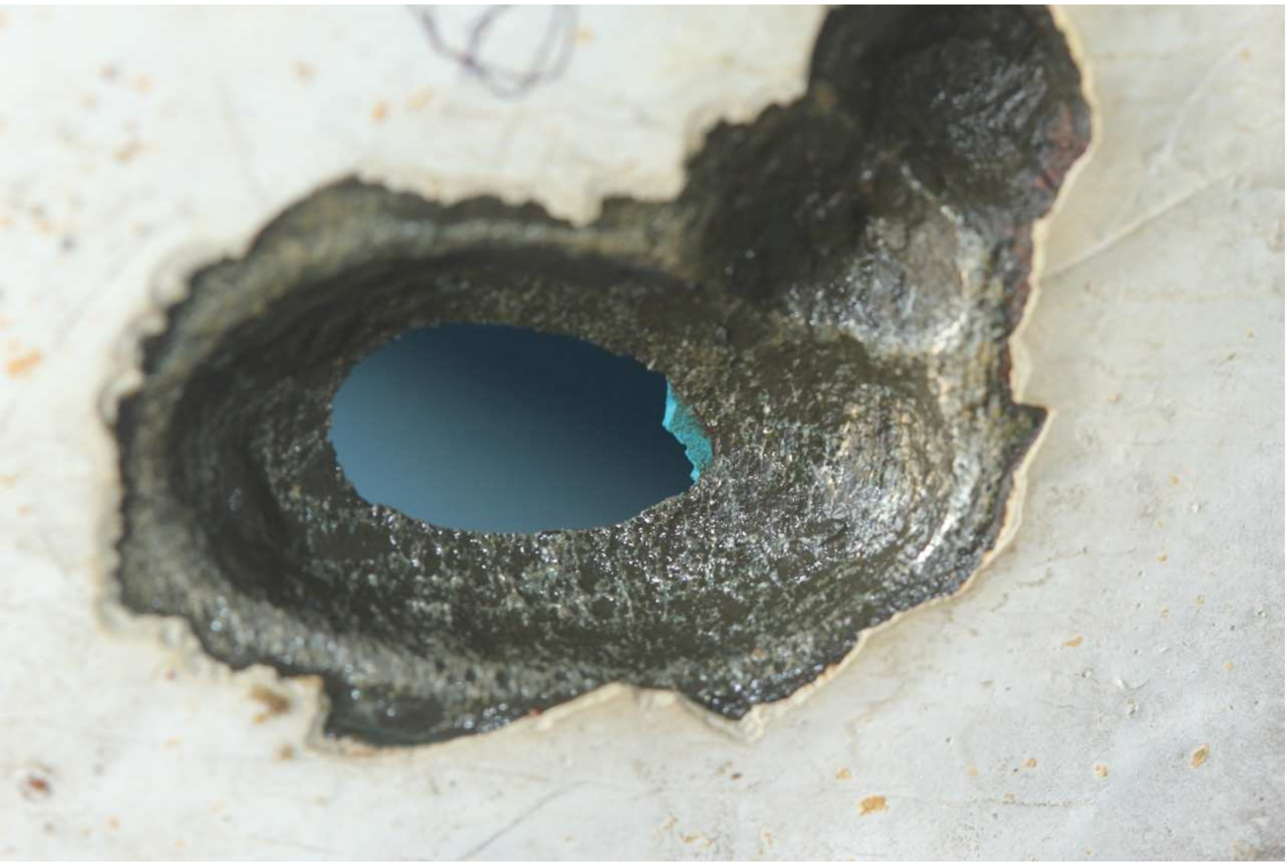
The penetration rate of 9mm in a period of less than 14 months is excessive, and is indicative of anodic interference, even though typical stray current corrosion morphology was not apparent. It was, however, noticable that there were no tubercles or encrustations on the outer surface of the pipe. This would not be expected for straightforward SRB or soil corrosion, given the 7-fold increase in volume of iron corrosion products and the loss of 9mm of steel.

Corrosion sites were associated with coating damage, and the overall external coating thickness (DFT) was below specification in areas. The low DFT was not a primary factor in the observed corrosion.

The following photographs illustrate the observed condition of the Tee.

Corrosion site at location of coating damage prior to examination.

Corrosion pit beneath coating filled with corrosion product.



Corrosion pits showing shiny scalloped surface after removal of corrosion product

Internal view of corrosion perforation.

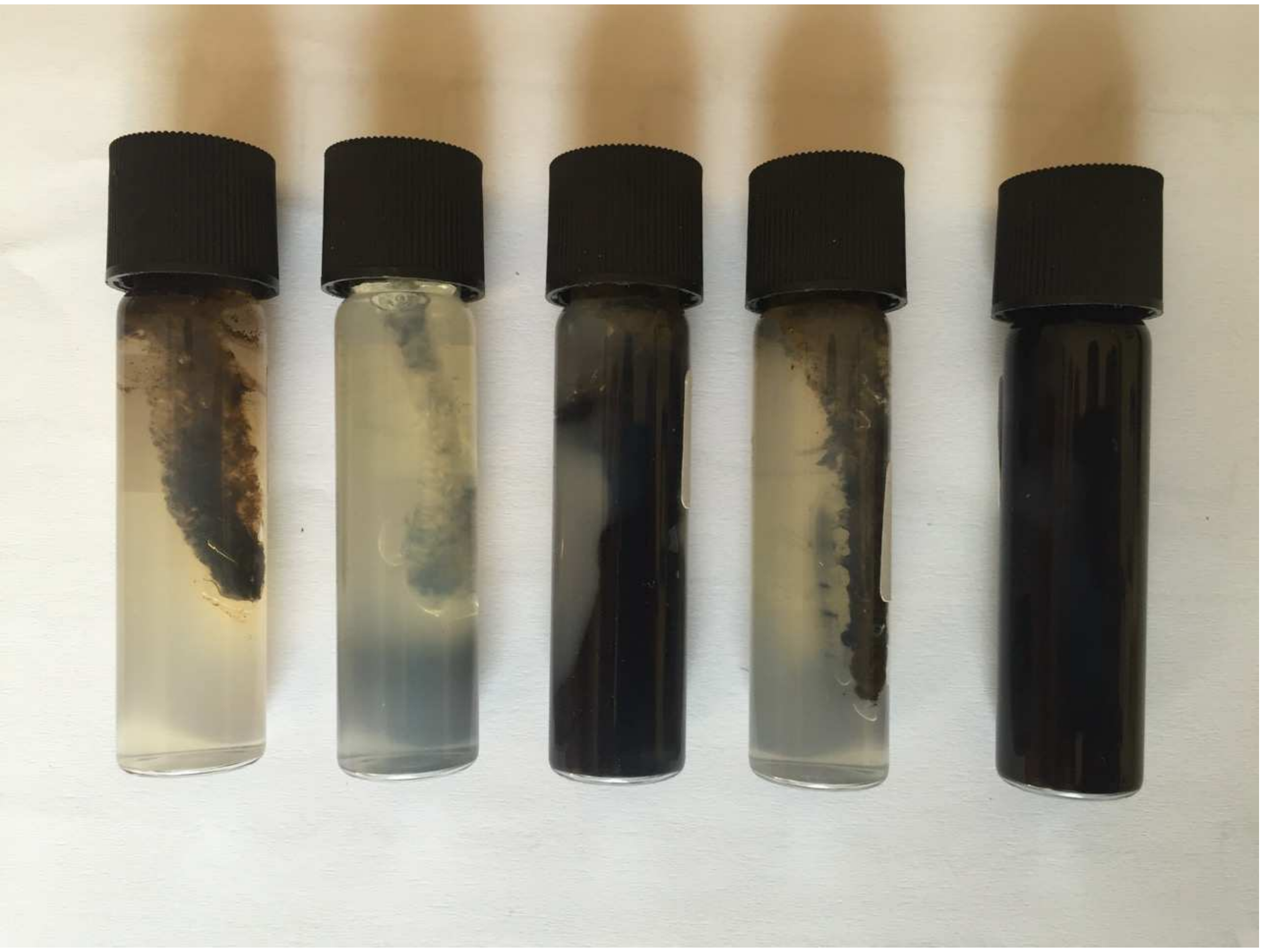
Internal corrosion at defects on internal weld - not significant.

3. BACTERIAL AND CHEMICAL ANALYSIS

Bacterial analysis was effected by means of species specific culture kits.

Suphate Reducing Bacteria (SRB) were detected using the Sanicheck® SRB culture kits from Biosan Laboratories.

Samples were taken from the various corrosion pits on the outside of the Tee. Positive results were found in 3 of the 5 sites tested. The photograph below shows the results of the SRB tests.



Bacterial corrosion is an anaerobic process, and further information can be obtained by analysing the Ferrous/Ferric iron ratio and sulphur concentration in the corrosion product. Bacterial corrosion results in an increase in the sulphur/iron ratio in the corrosion product compared to the parent steel which has corroded.

Three corrosion product samples were analysed which gave results of 0,15% 0,15% and 0,23% S, a concentration factor of between 5 and 8 compared to <0.03% S in the pipeline steel.

4. PIPE / SOIL POTENTIAL MEASUREMENT

The measurement of the potential between a buried steel structure and the soil, with reference to a standard electrode, is a simple method of determining the tendency of the pipe to corrode. This is the technique used during construction monitoring to determine requirements for, and effectiveness of, temporary cathodic protection.

The reference electrode is buried in the soil above or near the pipe, with the circuit to the pipe completed via a high impedance voltmeter. For a buried steel pipe, the significance of the pipe-to-soil potential may be summarised simplisticly as follows:

PIPE-TO-PIPE POTENTIAL	
($V_{(CSE)}$)	**PHENOMENON**
More positive than - 0.4	Tendency to corrode faster than natural rates.
- 0.4 to - 0.65	Corrosion at natural rates.
- 0.65 to - 0.85	Tendency to corrode slower than natural rates.
More negative than - 0.85	Natural corrosion ceases.
More negative than - 0.95	Bacterial corrosion ceases.
More negative than –1.15	Cathodic Disbondment of coating and hydrogen embrittlement of high strength steels may occur

Cathodic Protection is used to depress the pipe-to-soil potential to the required potential. In the presence of SRB this is -0.95V (CSE). This may be temporary (during construction) or permanent, and should be implemented from the time the pipe is backfilled (SANS 15589-1 National Forward).

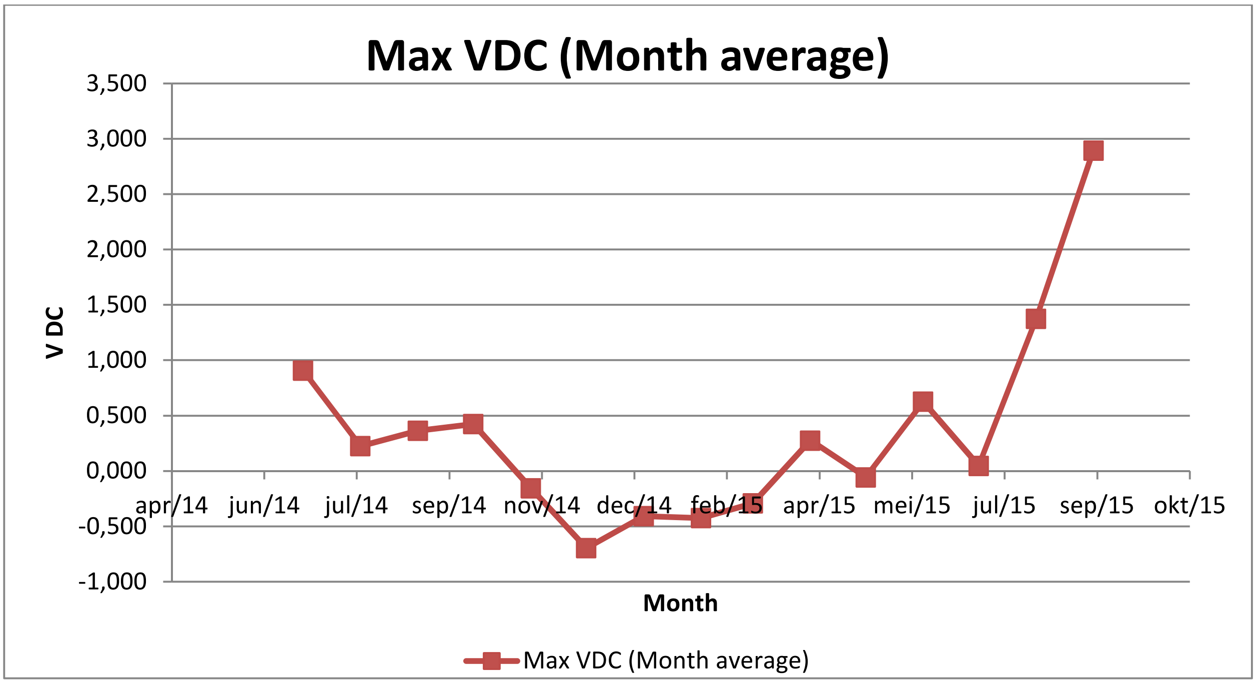
The corrosion rate of steel in soil typically increases at the rate of 1mm/yr for every 500mV shift in the positive direction from the natural potential. (Handbook of Cathodic Corrosion Protection, 3rd Edition, W von Baeckmann, W Schwenk & W Prinz. pp 150)

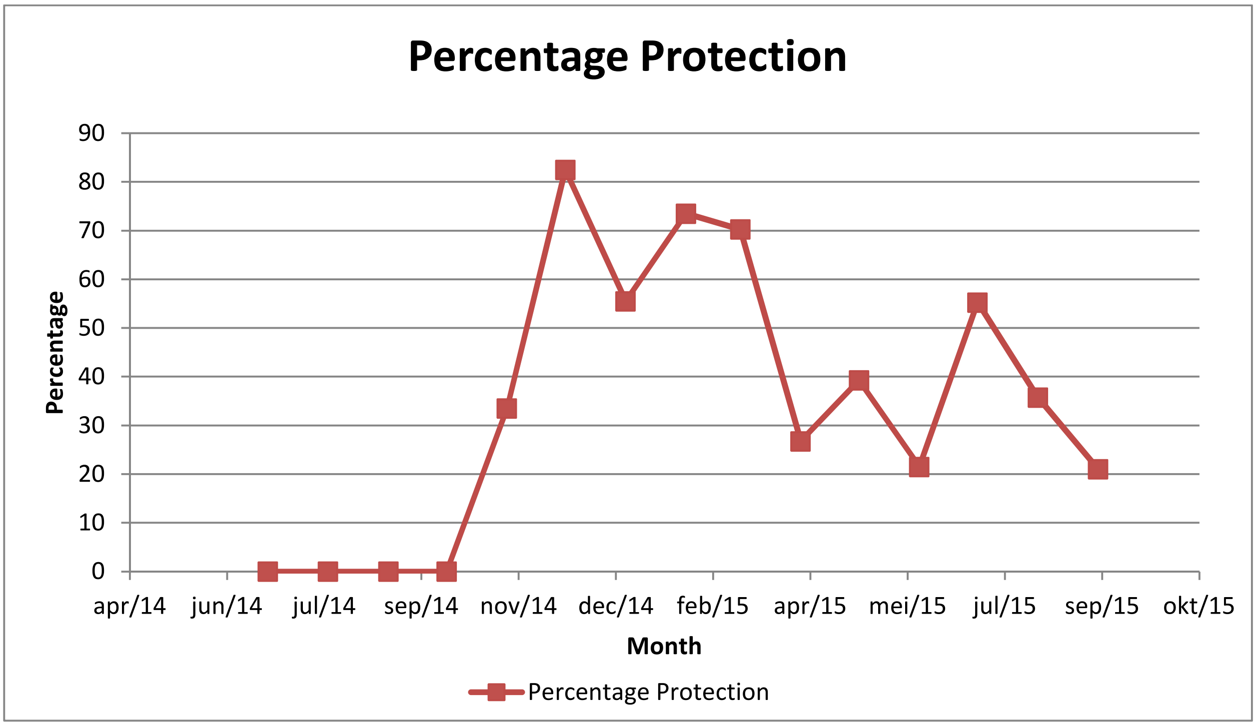
Cathodic protection is considered effective if the pipeline potential is maintained more negartive than the protection criterion for at least 95% of time, based on potential recordings. (AS 2832-3)

At the time of the inspection, the pipeline potential at the scour Tee was +2V (**two volts positive**) (CSE) and the temporary cathodic protection which had been installed was not operational.

The potential history of this section of the pipeline is shown in the graphs below, which have been taken from the monthly monitoring records for the pipeline.

It is clear from these graphs that this section of the pipeline has been at risk since July 2014 when it was installed.





5. DISCUSSION & CONCLUSIONS

CIRIA report C634 quotes corrosion rates in excess of 1mm/yr in offshore conditions subjected to ALWC. EN1374 quotes corrosion rates of 2mm/yr in similar conditions.

Based on the potentials observed, an average rate of 2mm/yr could be expected.

The actual corrosion rate was >8mm/yr which is double the arithmetic combination of the SRB and anodic interference.

From these results, it appears that the combined effect of SRB corrosion and anodic interfernce is synergistic in the negative sense, in that the combined corrosion rate is higher than the sum of the parts.

In summary - the following conclusions may be drawn:

- The perforation of the Tee was caused by external corrosion at coating defects.
- The corrosion mechanism was bacterial corrosion, exacerbated by anodic potentials resulting from the influence of the nearby cathodically protected pipeline.
- Temporary cathodic protection during construction at this location had not been implemented.
- Coating defects on the internal lining showed the onset of corrosion, but no significant metal loss had occurred.
- It is critical that temporary cathodic protection of pipelines must be undertaken and maintained during construction when monitoring data indicates the existence of anodic potentials..

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