Cathodic Protection is Essential to Mitigate Soil Side Corrosion of Tank Bottom Plates

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Summary

Soil-side corrosion of the bottom plates of above ground storage tanks (AST) is one of the major corrosion challenges in petrochemical complexes, oil & gas and other industries, especially the tanks that were constructed on thick concrete pads or concrete pads lined with asphalt. Asphalt and concrete layers deteriorate with time leading to origination of cracks that provide a path for ground water with dissolved chemicals to come in contact with the tank bottom plates, thus causing severe corrosion. Product leakage due to corrosion of tank bottom plates poses a serious threat to the plant and plant personnel, if the product stored is highly inflammable, hazardous and/or carcinogenic.

Keywords: Above ground Storage tanks (AST), Carbon Steel (CS), Stainless Steel (SS), Asphalt, Concrete pads, Corrosion, Cathodic Protection (CP), HDPE liner (High Density Polyethylene) and Clean Sand

1 Introduction

One of the most important facilities in petrochemical plants are ASTs which hold firewater, feedstock and vast variety of chemicals used in the successful operation of plants. Furthermore, they also a play a vital role in terminal services which operates the tankage and loading facilities at industrial ports.

Mostly ASTs are built on base foundations made of concrete pad, asphalt pad, sand cushion and asphalt pad atop a concrete pad or asphalt-concrete pads atop sand gravel. In some base foundations HDPE liner (High Density Polyethylene) is also installed beneath the concrete and asphalt pads to prevent the ingress of ground water and contaminants. The main purpose of concrete and asphalt pad is to provide corrosion protection for the tank bottom during design life of the tank. Coating has also been applied to few tank bottom plates as an additional corrosion prevention measure.

In the recent years industries have experienced many failures of tank bottom plates seated on asphalt and concrete pads due to severe soil side corrosion, especially the huge diameter tanks. Many people still believe that concrete and asphalt pads are sufficient to provide corrosion protection for more than 25 years and there is no need of CP. Few people raise an argument by asking, “Is CP needed if the plant is designed for 25-30 years”, whereas the fact is that even though the plants are initially planned to run for 25 years they continue running beyond 40 years. Some people are in a wrong assumption that ICCP system is very costly from the design, installation, monitoring and maintenance point of view, however CP is the most economical and viable corrosion prevention method in the long run.

This paper emphasizes the disadvantages of building huge diameter ASTs on asphalt and concrete pads as a corrosion prevention method and explains the advantages of building tanks on clean sand with a well-designed impressed current cathodic protection (ICCP) system. Two tank bottom soil side corrosion cases has been presented in this paper, of which one case is for carbon steel tank and another for stainless steel tank.

2 Corrosion Mechanism

There are two ways in which corrosion can be initiated underside the tank bottom plates.

2.1 Ingress of moisture/water and environmental contaminants through damaged sealant around tank periphery

A non-conductive polymeric sealant is used to cover the gap around the tank periphery and tank foundation to prevent the ingress of moisture, rain water and environmental contaminants such as chloride, sulphates, etc. Depending on the quality and workmanship of the sealant it may either last for few days or few years. Once the sealant is damaged it provides a path for the ingress of moisture/water and environmental contaminants which is further accelerated by the breathing action of tank bottom plate that occurs during normal tank filling and emptying operations. Thus galvanic corrosion occurs due to direct contact of the tank bottom plate with moisture/water, chloride and sulphates. It the tanks are operating at high temperatures then the corrosion process is further accelerated.

2.2 Ingress of ground water and dissolved chemicals through deteriorated asphalt and concrete pads

During operation of the tank, the bottom plate is subject to flexure and settlement due to normal tank filling and emptying operations of the product stored. The asphalt and concrete pads are prone to be damaged by this process. Furthermore, asphalt and concrete pads undergo degradation and cracking with time providing a path for subsoil ground water and dissolved chemicals to come into contact with the tank bottom plate, allowing corrosion to occur. [4] It is well documented that soil in gulf sea coast areas contains high amount of aggressive ions such as Chlorides and Sulphate and in contact with water it forms a good electrolyte.

3 Corrosion of 32 meter diameter SS 304 hydrocarbon storage tank

3.1 Background

The 32 meter diameter SS 304 tank was constructed in 1995 and is designed to be placed on thick concrete which and asphalt pads. The operating temperature of tank ranges from 70 to 80 degree Celsius.The tank is designed in accordance with API 650. The tank bottom has not been equipped with CP system.
The tank was opened up and saturated low frequency Eddy current examination (SLOFEC) of tank bottom plate revealed corrosion damage on soil side.

3.2 Investigation and findings

Visual examination, microbiological analysis, chemical analysis, and metallography were carried out on the samples of the tank bottom plate received.

3.2.1 Visual Examination

The two tank bottom metal samples submitted are shown in figure 1 and figure 2. Reportedly, severe corrosion was noted at the soil side sample shown in Figure: 1 and the characteristics of the attack appeared to be microbiologically induced. Damages as pits have narrow throat which widen at the middle and have smooth spherical bottoms. Further microbiology tests were carried out to confirm the presence of bacteria. [1]

Micro cracks were observed on the product side of the second sample as shown in figure 2. Further metallographic and tests were conducted to study the cracks.

Figure 1: The tank bottom sample as received showing severe corrosion on soil side

Figure 2: The dye penetrated sample showing cracks adjacent to weld

3.2.2 Metallographic Analysis

- Cross section of the cracks can be seen under stereo microscope in Figure 3. The cracks are branched & transverse to the weld direction and these cracks originated at the underside of the base plates.
- Figure 4 reveals highly branched cracks, typical of Chloride induced stress cracking corrosion (CISCC).
- Figure 5 reveals that cracks are branched, trans-granular and inter-granular, which is also a typical of Chloride induced stress cracking corrosion (CISCC).

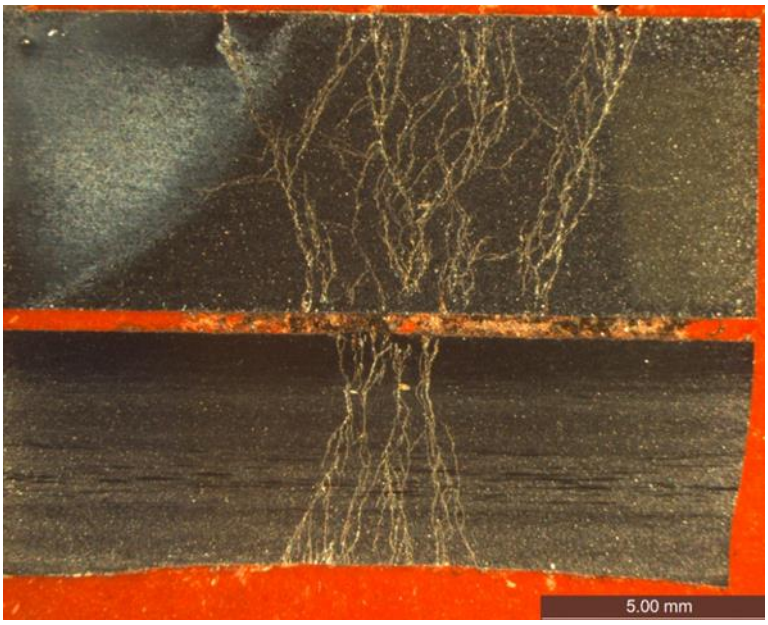

Figure 3: Stereo microscopic view of the crack originating in upper and lower plates at the lap joint

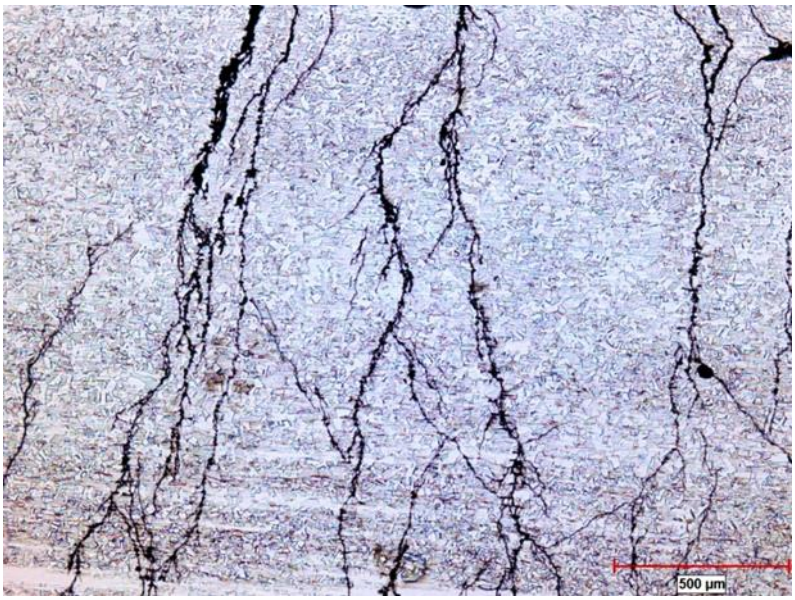

Figure 4: Micrograph of cross sectional view revealing transverse cracks; etchant oxalic acid

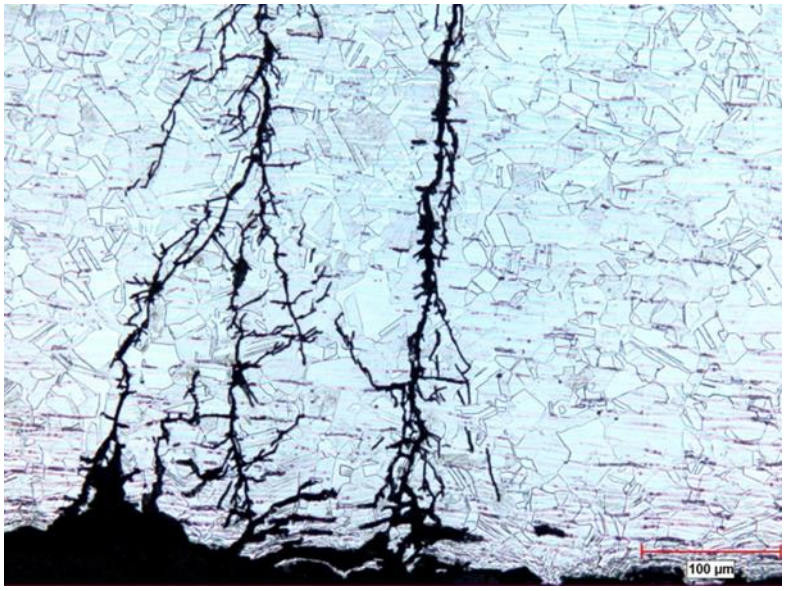

Figure 5: Micrograph revealing branched, trans-granular and Inter-granular cracking

3.2.3 Microbiological Analysis

- The damaged SS304 tank bottom samples and asphalt samples were analysed for the presence of bacteria and positive results were observed as shown in Table 1 and Table 2.
- Positive results confirmed that MIC type of damage has occurred and both SS304 damaged sample and asphalt sample contained aerobic bacteria.

Table 1: Test Report on Corroded Steel Plate Sample

Test description	Units	Test method	#1	#2	#3
Total Bacterial Count	(CFU/g)	BAM Jan 2001	7.7×10^3	7.4×10^3	5.8×10^3
Aerobic Bacterial Count	(CFU/g)	BAM Jan 2001	1.9×10^3	2.8×10^2	1.8×10^3
Anaerobic Bacterial Count	(CFU/g)	CCFRA 3.6.1:2003	LT 10	LT 10	LT 10
Iron Bacteria	(Detection)	Microscopic	ND	ND	ND
Sulphate Reducing Bacteria	(MPN/100ml)	ASTM D 4412	LT 1.8	LT 1.8	LT 1.8
Microscopic Examination (Morphological & Characteristics)	(Detection)	Microscopic	GP	GP	GP

GP = Gram Positive ND = Not Detected LT= Less than the detection limit

Table 2: Test Report on Asphalt Particles

Test description	Units	Test method	Results
Total Bacterial Count	(CFU/g)	BAM Jan 2001	1.4×10^3
Aerobic Bacterial Count	(CFU/g)	BAM Jan 2001	7.8×10^2
Anaerobic Bacterial Count	(CFU/g)	CCFRA 3.6.1:2003	LT 10
Iron Bacteria	(Detection)	Microscopic	ND
Sulphate Reducing Bacteria	(MPN/100ml)	ASTM D 4412	LT 1.8
Microscopic Examination (Morphological & Characteristics)	(Detection)	Microscopic	ND

GP = Gram Positive ND = Not Detected LT= Less than the detection limit

4 Corrosion of 61 meter diameter CS Chemical Storage Tank

4.1 Background

The 61meters diameter carbon steel tank was constructed in 1982-83 and is designed to be placed on thick concrete and asphalt pads. Underneath the concrete and asphalt pads HDPE liner is installed. The operating temperature of tank ranges from 70 to 80 degree Celsius. The tank bottom has not been equipped with CP system.

4.2 Tests and Findings

In 2004 the tank was taken out of service for inspection of the tank bottom. MFL scanning revealed loss of thickness by soil side corrosion and metal loss ranged from 0% to 100%. All locations on the floor showing loss of thickness above 40% were patched as per API 653 standard. The tank was then put back in service. Underneath the concrete and asphalt pads HDPE liner is installed which also eliminates possibility of CP system application as the protective CP current will be shielded by HDPE liner.

Subsequently in late 2008, the tank was again taken out of service and inspection of tank bottom was carried out by NDT methods. The corrosion was found to be localized in scattered location and thickness loss ranged depending on the condition of soil in different locations. Many holes were found and also areas were metal loss percentage was above 40% were detected.

Figure 6: Holes in tank bottom plate near sump area

Figure 7 & 8: Holes in tank bottom plate

5 Conclusion

- SS304 tank bottom plate has undergone Microbiologically-Influenced corrosion (MIC) attack followed by Chloride Induced Stress Corrosion Cracking (CISCC). SS304 is a susceptible material for CISCC and MIC attack was most likely triggered by specific microorganisms, either aerobic or anaerobic bacteria. Thus, the bottom plate failed due to multimode corrosion damages.
- Carbon Steel tank bottom plate underwent localized soil side corrosion due to the damage of concrete and asphalt pads.
- The root cause of the problem for both SS304 and Carbon Steel tank bottom plates is the degradation of asphalt [2] & concrete pads with time that provided

a path for the ingress of ground water and dissolved chemicals allowing corrosion to occur.

- Awareness is still not available among the corrosion practitioners on disadvantages of constructing tanks on asphalt and concrete pads.
- The most effective solution to mitigate the soil side corrosion is to replace the corroded tank bottom plate with new tank bottom plate and install impressed current cathodic protection (ICCP) system [Figure 9 & 10].
- Application of Cathodic protection can also reduce or eliminate stress corrosion cracking (SCC) in many environments because it stops the corrosion process; particularly pitting corrosion that can act as initiation sites for SCC [6].
- New tanks shall not be constructed on asphalt or concrete pads, especially large diameter tanks.
- The tanks shall be built on clean sand with resistivity ranging between 10,000 – 30,000 and equipped with ICCP system, utilizing mixed metal-oxide (MMO) coated titanium ribbon (grade 1 titanium) in grid pattern which is currently best CP system for protection of tank bottom plates.
- The recommendations may not be consistent with applicable local laws and regulations, and the reader should carefully review such laws and regulations to determine applicable requirements for construction of ASTs.

Figure 9: Removal of Asphalt & Concrete Pads

Figure 10: Installation of New ICCP System utilizing MMO Anodes

7 Acknowledgement

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