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15th July 2013
Ref. # CME/SLE-KA/0713/825

Messrs. Petro Rabigh
Attn. Mr. Katsuo Kirita

Subject: **Corrologic™ Vapor Corrosion Inhibitor System Technical Proposal**

Dear Mr. Kirita,

With reference to the above subject, we are pleased to hereby submit our proposal for the supply and installation supervision of the Corrologic System for Tank No. F50-T35 as follows:

BACKGROUND

Soil Side Corrosion in Aboveground Storage Tanks (AST)

Soil side corrosion of aboveground storage tanks is a chronic problem in the oil and gas industry in the GCC countries and in the world at large. Corrosion of the underside of the tank bottom plates leads to metal loss and ultimately perforations in the tank floor. The results of such failures are dramatic on multiple fronts: loss of product, costly repairs, and environmental impact and safety concerns in the case of flammable fluids.
Traditionally cathodic protection (CP) has been used for corrosion management of tank bottoms. However, experience has shown that CP fails to provide adequate protection in some types of AST construction. Gaps in protection allow localized corrosion which leads to early failure.

Corrosion Mitigation with VpCIs

In the last thirty years, the use of amine carboxylate VpCIs has grown significantly. With more than 300 tanks currently protected by VpCI systems, confidence is growing in this important technology.
Engineered systems utilizing VpCI technology offer an important alternative for mitigation of tank floor corrosion. These systems are economical, effective, and can be installed on a retrofit basis without disrupting tank service.
A developing history of corrosion rate data provides confidence that when the VPCI chemistry is effectively delivered under the tank bottoms, soil-side floor plate corrosion will be mitigated. VPCIs are effective alone, or in combination with CP.

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Fundamentals of VPCI Operation

It is important to recognize that VPCI chemistry/technology is very mature and well proven for over 30 years. VPCI solutions for corrosion mitigation are utilized by many major corporations in most regions of the world for a wide variety of applications.
Amine carboxylate-based VPCIs are used beneath aboveground storage tanks (ASTs). These environmentally friendly products are effective for prevention of metal corrosion in three phases: on the surface of the steel in contact with the sand tank pad materials, at the air/sand interface, and in the vapor space above the sand. When a VPCI output is released within an AST interstitial space, protective vapors disseminate until equilibrium, determined by the partial vapor pressure, is reached. The mechanism for corrosion control is the formation of a monomolecular layer throughout the soil-side surface of the tank floor. VPCI molecules adsorb on the steel surface to suppress both metal dissolution and the reduction reaction (both the anodic and cathodic processes). This adsorption is accomplished without the need for direct contact of the VPCI chemical on the metal surface.

Corrologic Corrosion Management System

Corrologic is an engineered system utilizing Vapor phase Corrosion Inhibitors (VPCIs) for the protection of tank bottoms against soil side corrosion.

1. Application of the VPCI into the interstitial space in such a way that effective distribution of the chemistry is ensured.
2. A corrosion rate monitoring system utilizing electrical resistance probe technology to measure real-time rate of corrosion within the interstitial space near the tank floor.
3. A replenishment system consisting of perforated PVC pipes distributed in the sand pad allowing future injection of VPCI.

ER Probe Monitoring Basics

ER Probes are used to monitor the performance of Corrologic$_{TM}$ VpCI® Systems.
Unlike reference electrodes, ER probes are designed to analyze the corrosiveness of the environment in which they are located. Corrosion is measured at the sensing area of the probe.
The data output is mills per year of metal loss. With our systems the probes are used to ensure the inhibitor is controlling the corrosiveness of the environment and keeping it low. Reference electrodes on the other hand are used to measure structure to soil potentials. The data output is millivolts. This millivolt data is then compared to NACE criteria in order to determine if the structure meets the minimum criteria for cathodic protection. If the data indicates the structure has adequate cathodic protection it is then assumed that corrosion of the structure is controlled.

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HISTORY WITH CORROLOGIC IN ABOVEGROUND TANKS

- In 1993, Rials & Kiefer of Conoco Oil published a technical paper presenting results from testing a variety of corrosion control options for double bottom tanks.[1] One of the corrosion prevention methods tested included Cortec vapor phase corrosion inhibitor mixed with a typical tank pad material. Corrosion was monitored and measured over an extended time period. Almost no corrosion developed in the presence of the VpCI®.
- One of the first known AST applications of the VpCI® technology in the U.S. was by Motiva in Florida. Cortec VpCI was installed in a water slurry mixture under (17) ASTs in Florida between the years of 2000 - 2001. Electrical resistance corrosion rate probes were installed under each tank to monitor the inhibitor effectiveness. Approximately 5-years after VpCI® application the corrosion rate probe data was provided by Motiva. The corrosion rates were still very low. The rates ranged from 0.150 mils per year to 0.720 mils metal loss per year.
- Currently about (12-15) major pipeline companies operating ASTs in the U.S. utilize VpCI® chemistry to control corrosion on tank floors. These include Plains All American, Buckeye Pipeline, Centurion Pipeline, Holly Frontier, Valero, NuStar and TransMontaigne.
- Aramco were the first in the Middle East to adopt this technology after the implementation of a pilot project in 2011. Migration through commonly used bituminous sand and effective corrosion protection was demonstrated by the corrosion monitoring system. Results of this pilot were published in paper # 2242 published at NACE Corrosion 2013 Conference.
- It is estimated that over (300) ASTs have Cortec Corrologic applied below the floors.

ATTACHMENTS

- VpCI 609S product data sheet
- VpCI 609S Material Safety Data Sheet
- NACE Article – June 2011
- NACE Paper #2242 – Corrosion 2013

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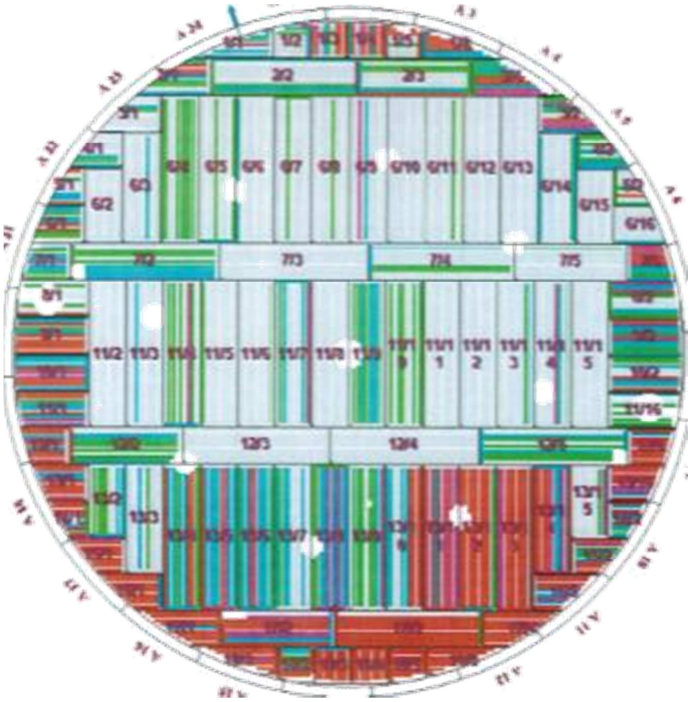
CASE DISCUSSION

Tank No. F50-T35 is a 45 m potable water tank constructed in 1986 on a 10 cm asphalt layer with no CP system or HDPE liner.

The above mentioned tank was taken out of service for T & I on June 05, 2002 up to November 28, 2002. Inspection revealed that corrosion pits were spread all over the bottom plates. UT thickness measurements showed that all annular plates have severe underside with significant reduction in material thickness, which in turn resulted in replacing all of them using 8mm CS plates.



In 2013, the tank was again taken out of service for T & I. MFL inspection was carried out on the entire bottom plates and UT was utilized in the areas where inaccessible for MFL scanning. Results showed that two rows from the North side of the tank were found with full plate hole and soil side corrosion and some inboard plates also were found with underside corrosion, deep surface pitting and holes. Total defective area is 3240.38 ft^2 out of 17152 $ft^{2.}$.

Reinforcement by patching with additional plates was initiated to patch perforations and compensate thickness in areas of high thickness loss.

After our site inspection we found out that asphalt layer is extremely hard and in some areas eroded and damaged, we also found out that air gaps exist between the bottom plates and the asphalt layer, mainly at the center and periphery that will facilitate the injection of the VpCI powder.

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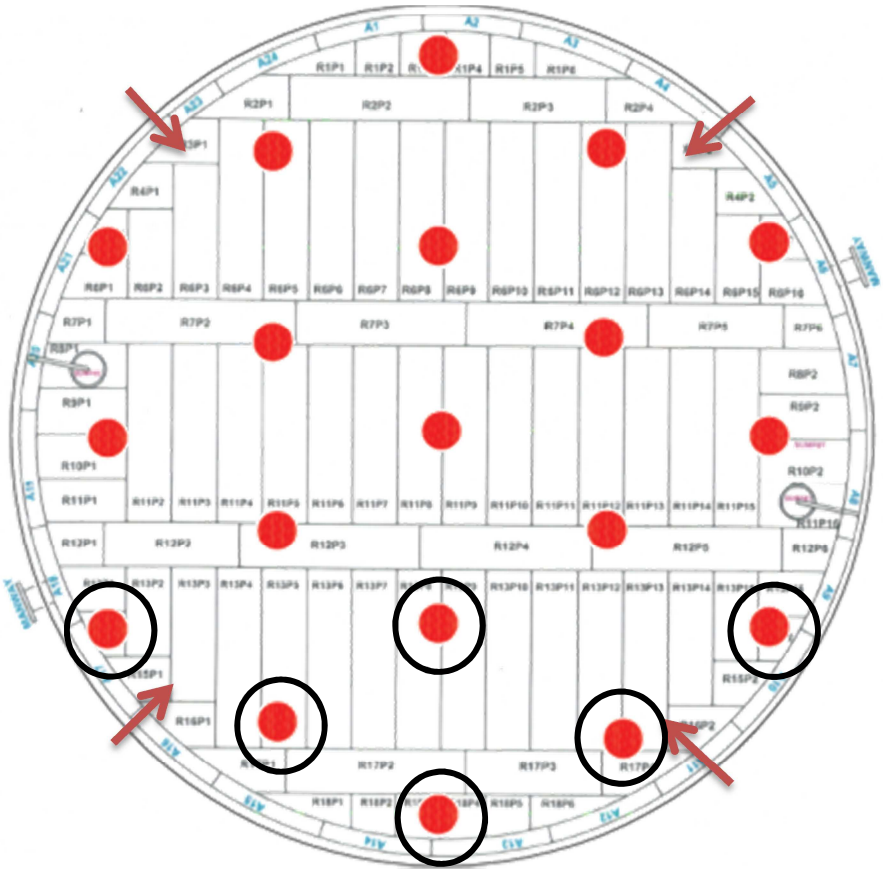
PROPOSED REPAIR STRATEGY

i. Install 19 temporary 25 mm injection ports in different locations of the tank floor to fog Corrologic Powder as per the following layout:



VpCI 609S injection ports (19 places)
ER Probes (4 places)

ii. Inject 1 drum of 22.3Kg of Corrologic Powder using pneumatic delivery system through each port. In ports close to the corrosion island in the north side of the tank, highlighted in black circles, 2 drums of 22.3kg will be injected.
iii. Weld patches over the ports after Corrologic Powder application.
iv. Introduce sleeves and install ER Probes in the specified locations.
v. Complete remaining blasting and lining activities to place the tank back into service.
vi. Collect data on monthly basis.