Subject: Literature Review and Evaluation of Efficacy of Volatile Corrosion Inhibitors (VCI) for Mitigating Soil-Side Corrosion on Aboveground Storage Tanks

Available literature and references indicate that Volatile Corrosion Inhibitor (VCI) technology has been tested for its efficacy in mitigating soil-side corrosion on storage tank bottoms first time by Conoco Philips in 1993. The tests showed promising results as described in their published paper entitled "Evaluation of Corrosion Prevention Methods for Aboveground Storage Tank Bottom ", attached is a copy of the technical paper for review [1]. This technology was first approved by the Florida Department of Environmental Protection in 2002 for use in the protection of tank floors in the event of a failure to repair or modify the existing cathodic protection system, attached a copy of the facsimile for review[2]. The technology continued to develop and prove promising results in the field which led the state of Florida to approve the use of VCI along with cathodic protection systems or as a standalone solution, as indicated in paragraph (d) of Section 62-762.501 of Florida Administrative Code of 2013[3].

The first documented large scale field application was in 2006, where VCI technology was applied on 22 storage tanks in the United States. In this project, the corrosion rate was monitored for 6 years, and the results showed that volatile corrosion inhibitors helped maintain corrosion rates below 4.1 mpy, attached a copy of the report for view[4].

In Saudi Arabia, the first documented application of this technology was in 2011. It was first applied on a 104 meter crude oil tank for Aramco. VCI Powder was injected through the tank floor while the tank was out of service for inspection. The results were published in a NACE paper in 2013 and showed VCI technology reduced soil-side corrosion rate by 92% as measured by corrosion probes[5]. In 2014, Saudi Water Conversion Company used this technology to protect a 15 meter in diameter fire water tank by injecting VCI liquid through the concrete ring wall. The published

results showed that VCI technology as able to reduce soil-side corrosion by around 90%[6]. Since then, VCI technology has been gaining wider and wider acceptance and used by other companies in the Kingdom such as SABIC and the Royal Commission. A sample of project reference list for tanks protected by this technology in the Kingdom and the rest of the GCC countries is provided for review[7].

With regards to international industry standards, VCI technology is recognized in paragraph 12.5 of API 2610, a copy of the standard is provided for review[8]. In April 2021, the American Petroleum Institute published a technical report API 655 detailing the use of volatile corrosion inhibitors to protect storage tank floors against soil-side corrosion, attached to a copy of the report for reveiw[9].

Several NACE technical papers have been published in the past eight years on the compatibility and impact of VCI technology on cathodic protection workings and system components. A paper in 2016 discussed the results of an experiment that proved that combining both techniques, VCI and CP, provided the best results. The combined approach resulted in maintaining an average corrosion rate of less than 1 mpy compared to 3 mpy for each technology separately[10]. In 2017, a scientific paper was published that examined the effect and interactions between VCI and cathodic protection from the point of view of polarization and cathodic protection demand. The experiment showed that the VCI chemistry used acted as a cathodic polarizer and reduced the cathodic protection current required by 40%[11]. In a sequel study in 2018, it was shown that not all types of volatile corrosion inhibitors are compatible with cathodic protection systems[12]. API 655 report in paragraph 7 highlights the complementary effect between cathodic protection and volatile corrosion inhibitor technology, as well as possible considerations to be taken into account by tank owners and operators when combining both systems.

On the ability of VCI technology to provide long-term protection, the results of a long-term comprehensive study based on MFL floor scan data was published at NACE Corrosion 2020 conference[13]. The results showed VCI technology was able to provide long term protection.

Based on a review of available literature and documented field applications, the use of VCI technology can be recommended to provide protection against the soil-side corrosion in the following cases:

1. Tanks that do not have cathodic protection system and installing a system is not economic or practical.
2. Tanks that have cathodic protection system but don't meet NACE protection criteria and retrofitting existing system is not economically or practically feasible.
3. Tanks constructed on oily sand or asphalt pad. This type of tank pad reduces the efficiency of cathodic protection as it shields cathodic protection current from reaching to the tank floor as stipulated in paragraph 5.3.5 in API 651.
4. Tanks that that historically showed high level of soil-side corrosion and tank operator wants to improve the service life of the tank or extend the next inspection interval

The recommendation is conditional on the provider of volatile corrosion inhibitor technology demonstrating their ability to provide a thorough study of each tank and to have a strong track record of implementing this technology in the Kingdom for at least 10 years.

References:

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3. Florida Administrative code Chapter 62-762 - ABOVEGROUND STORAGE TANK SYSTEMS
4. T. Whited, "Review of CorroLogic™ Systems for Soil-side Corrosion Control on ASTs"
5. T. Whited, X. Yu, R. Tems, "Mitigating Soil-Side Corrosion on Crude Oil Tank Bottoms Using Volatile Corrosion Inhibitors," CORROSION/13, paper no. 2242 (Houston TX: NACE, 2013)

6. A. Meroufel, M. Al-Hajri, K. Abed “Mitigation of Soil-Side Corrosion on Storage Tank Bottoms in the Absence or Deficient of CP System”, 16th Middle East Corrosion Conference, paper no. MECCFEB16-7995 (Manama: NACE,2016)
7. Cortec Project Reference in Saudi Arabia
8. API STD 2610 “Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities” Third Edition, 2018
9. API TR 655 " Vapor Corrosion Inhibitors for Storage Tanks", First Edition ,2021
10. K. Abed, P. Panchal, A Gandhi, “Evaluation of Impressed Current Cathodically Protected API 650 Tank Bottoms in the Presence of Volatile Corrosion Inhibitor”, Corrosion 2016, paper no. 7600 (Vancouver: NACE,2016)
11. C. Pynn, K. Abed “Compatibility & Interactions between Cathodic Protection and a Vapor Phase Corrosion Inhibitor” CORROSION/17, paper no. 9232 (New Orleans, LA: NACE, 2017)
12. K. Abed, C. Pynn, “A study on the Effect of Volatile Corrosion Inhibitors on Impressed Current Cathodic Protection”, CORROSION/18, paper no. 11030 (Phoenix, AZ: NACE, 2018)
13. T. Whited, “Comparison of VCI and CP Performance Using Floor Scan Data from Several 10-Year-Old AST Floors” CORROSION/20, paper no. 15065, (NACE, 2020)