**Quarterly Report – Public Page**

**Date of Report:** *11th Quarterly Report, June 27, 2025*

**Contract Number:** *693JK32210001POTA*

**Prepared for:** *Government Agency: DOT and Co-funders*

**Project Title:** *Developing Corrosion Control Monitoring Technology for Hazardous Liquid Breakout Tanks*

**Prepared by:** *Pipeline Research Council International, Inc.*

**Contact Information:**  *Janie Norton,* [*jnorton@prci.org*](mailto:jnorton@prci.org) *703-205-1600 ext: 105*

**For quarterly period ending:** *June 30, 2025*

**1: Items Completed During this Quarterly Period:**

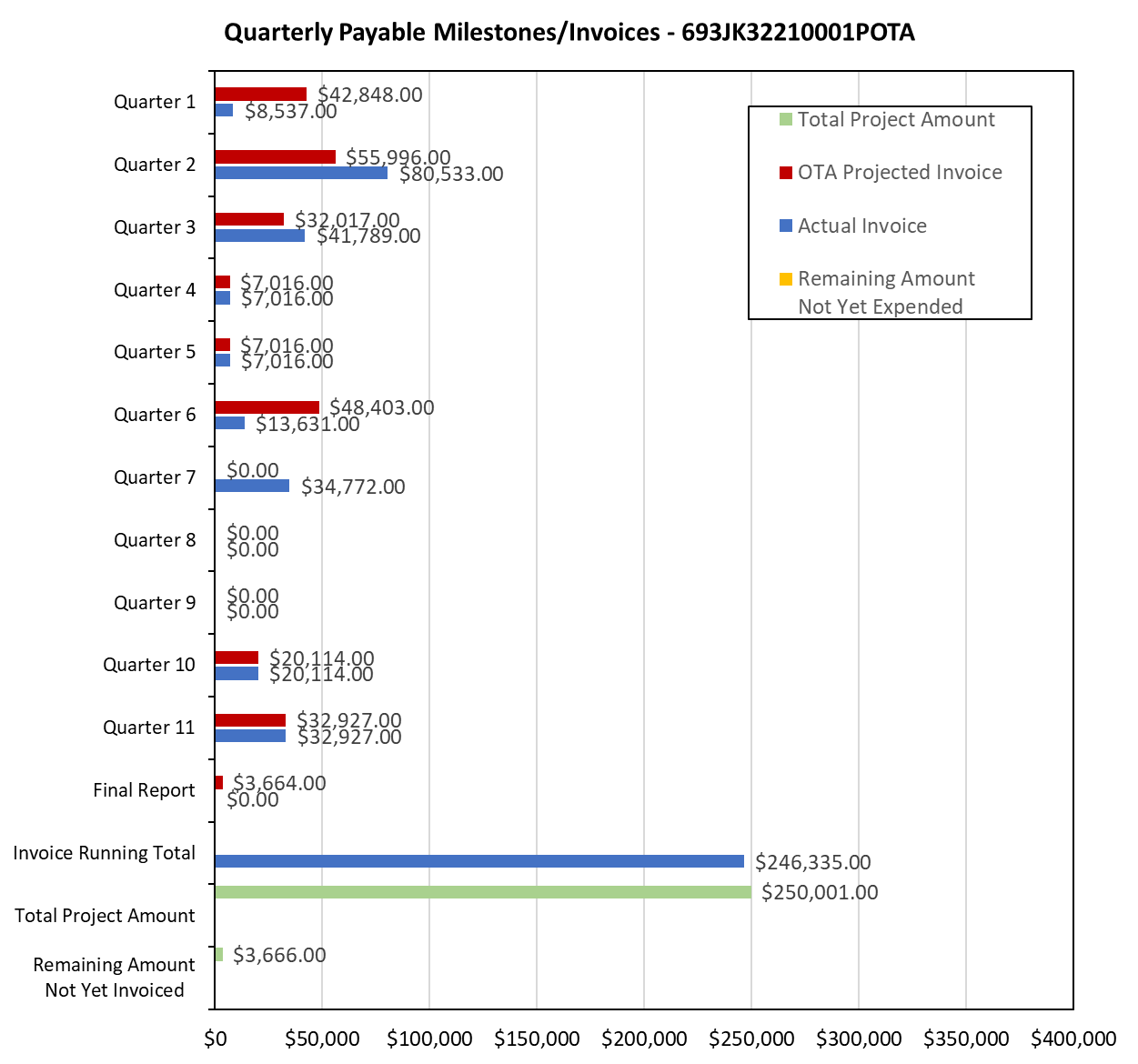
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Item***  ***#*** | ***Task***  ***#*** | ***Activity/Deliverable*** | ***Title*** | ***Federal Cost*** | ***Cost Share*** |
| 25 | 5 | Draft a set of recommendations to be submitted to the appropriate standard development organizations | Set of clear, concise recommendations to be submitted to the appropriate standard development organizations (e.g., AMPP, API, etc.) for incorporation into the relevant consensus guides, standards, and recommended practices manuals | $1,955 | $1,955 |
| 26 | 5 | Prepare a draft final report and submit it for review to the technical advisory panel and PHMSA | Draft Final Report | $26,562 | $26,562 |
| 27 | 5 | Quarterly Project Management & Status Update Reporting | Submit 11th quarterly report | $4,410 | $4,410 |
| 29 | N/A | Prepare & Present Paper at public event or publish paper in journal/magazine | Prepare & Present Paper at public event or publish paper in journal/magazine | − | − |
| 31 | N/A | Summary Report Academic Peer Review Comments on the Draft Final Report | Submit Summary Report Academic Peer Review Comments on the Draft Final Report | − | − |

**2: Items Not Completed During this Quarterly Period:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Item***  ***#*** | ***Task***  ***#*** | ***Activity/Deliverable*** | ***Title*** | ***Federal Cost*** | ***Cost Share*** |
|  |  | None |  |  |  |

**3: Project Financial Tracking During this Quarterly Period:**

Note that this chart reflects Federal share only.



**4: Project Technical Status:**

**Item 25, Task 5  Draft a set of recommendations to be submitted to the appropriate standard development organizations, Set of clear, concise recommendations to be submitted to the appropriate standard development organizations (e.g., AMPP, API, etc.) for incorporation into the relevant consensus guides, standards, and recommended practices manuals.**

Following are key recommendations developed under this project:

* The tank operators are recommended to have well distributed and frequented monitoring that can provide detailed map of the sand pad corrosivity. The monitoring probes such as coupons and ER probes coupled with sand-sampling can provided a reasonable assessment of the tank pad corrosivity throughout the tank bottom. Based on the assessment of the tankpad corrosivity and CP condition, the operators can device corrosion strategy such as using VCIs etc.
* As expected, API 653 inspection floor scan data from cathodically protected AST floors contained in this report highlighted the need for additional AST soil-side corrosion mitigation solutions. This report exhaustively evaluated soil-side corrosion mitigation of more than hundred and fifty cathodically protected ASTs. API 653 floor scan data from one VCI-treated tank was available and is provided in this report. The authors of this report are aware that VCI systems have been applied as the sole corrosion mitigation technology, and also applied in combination with cathodic protection, on a few hundred ASTs in the U.S. and internationally during the last decade. Therefore, many additional VCI-treated tanks will be due for API 653 inspections in the coming years. As with cathodically protected tanks, it is recommended that API 653 soil-side floor scan corrosion indication data from the VCI-treated tanks be thoroughly documented and analyzed. The data from such evaluations will foster growth in knowledge of VCI performance and serve as a vehicle for VCI product and application improvement considerations under field conditions.
* It is also recommended that tank operators exhaustively evaluate the tank CP systems when the out-of-service conditions exist and there are opportunities for sand sampling and tank bottom repairs. The operators can use the data obtained during such opportunities to analyze the CP systems and determine causes of CP underperformance. Such analyses will help tank operators decide future direction of the corrosion mitigation strategy such as implementing VCIs or enhancing CP systems.
* It is also recommended that the tank operators can use corrosion monitoring to determine the reinjection interval. Monitoring tools such as coupons and ER probes can be used to continuously monitor the VCI performance. The reinjection interval determination can be made based on the monitoring data and corrosivity conditions. The reinjection can be made during the in-service conditions, through the injection ports located at the tank perimeter. The VCI dispersion range was found to be 15-30 ft for highly corrosive conditions, therefore, it is recommended that operators use the port-to-port distance and injection depth from the tank perimeter such that VCIs can coverage is thought the tank bottom.

This item has been completed. This item links to item 12 in Attachment 1 Team Project Activities. This item also links to item 10 in Attachment 2 Project Deliverables.

**Item 26, Task 5  Prepare a draft final report and submit it for review to the technical advisory panel and PHMSA, Draft Final Report.**

The draft final report has been compiled and submitted o the project team and academia advisors. The report is also being submitted to the PHMSA along with this quarterly report.

This item has been completed. This item links to item 12 in Attachment 1 Team Project Activities. This item also links to item 10 in Attachment 2 Project Deliverables.

**Item 27, Task 5  Quarterly Project Management & Status Update Reporting.** Submit 11th quarterly report: The 11th quarter project meeting was held on June 12, 2025. This item has been completed. This item links to items 10 and 12 in Attachment 1 Team Project Activities. This item also links to item 10 in Attachment 2 Project Deliverables.

**Item 29, Task N/A  Prepare & Present Paper at public event or publish paper in journal/magazine, Prepare & Present Paper at public event or publish paper in journal/magazine.**

An abstract has been submitted to the 2025 API Storage Tank Conference & Expo which will be held during Oct 22-24, in Phoenix, Arizona. The project PI will present the key findings at the conference forum.

This item links to item 13 in Attachment 1 Team Project Activities. This item also links to item 12 in Attachment 2 Project Deliverables.

**Item 31, Task N/A  Summary Report Academic Peer Review Comments on the Draft Final Report, Submit Summary Report Academic Peer Review Comments on the Draft Final Report.**

Academia member comments on the draft final report are attached with this report.

**5: Project Schedule:**

The project is on-track as per the revised deliverable schedule. The project cost-based deliverables will be completed with the revision of the final report as per the academia member comments. The non-cost-based item 30 will be completed after submission and approval of the final report.

Appendix: Academia Member Comments on the Draft Report

**Technical Review of the draft PRCI report PR644-223603-R01 titled Developing Corrosion Control Monitoring Technology for Hazardous Liquid Breakout Tanks. EC-6-5B.**

*This review was done by Dr. Brendy Rincon Troconis*

The primary goal of the project reviewed was to identify and evaluate validated technologies for monitoring corrosion under the bottoms of breakout tanks, and to develop effective programs and processes for long-term monitoring.

This document presents a comprehensive and constructive technical review of the draft report to support improvement in clarity, accuracy, and technical consistency. Please see the comments below.

**General Comments:**

Ensure all abbreviations are defined upon first use and consistently applied throughout the report.

Avoid redefining terms repeatedly to maintain readability.

Ensure all figures (e.g., Figure 3-11) are properly cited with source attribution.

**Detailed Comments:**

Page iii, Abstract. “The VCI dispersion range in highly corrosive conditions was found to be 15-30 ft” Clearly state the environmental and experimental conditions under which the VCI dispersion range of 15–30 ft was observed. Define "highly corrosive conditions" with quantitative data where possible.

Page 3, Figure 3-1. The “PVS pipe slotted” seems to cover the entire ER probe, not allowing the probe to interact with the sand. Please modify the figure since it seems to be missing the opening of the PVC pipe at the tip or the openings that would allow the contact of the probe with the sand.

Page 18. “The foregoing discussion clearly demonstrates the factors that influence atmospheric corrosion and substantiates that the conditions necessary for classical atmospheric corrosion cannot develop in the interstitial space of double bottom tanks. While it is acknowledged that atmospheric corrosion can affect the shell of breakout tanks, the underside of the primary tank floor in double bottom tanks is not exposed to the same environmental conditions that can contribute to atmospheric corrosion. Even under the condition of condensing vapors on the underside of the primary tank floor, the absence of ionic species such as chlorides will result in an ohmic resistance path that cannot produce exchange rates that can contribute to injurious corrosion.” Clarify this information. It depends on the design. If the interstitial space is filled with concrete completely then it is definitely different from atmospheric corrosion, but if there are instances where air is in contact with steel, for example in situations where there are drainage grooves then the steel that is in contact with the air will be exposed to the atmosphere and lead to atmospheric corrosion. Also, ionic species and other chemicals could be transported there through winds depending on the location of the tank.

PAge 19. “A comparison of corrosion rates for the double and single bottom tanks are discussed.” Specify the precise surface under analysis—whether it is the primary tank bottom (interstitial side), secondary tank bottom (interstitial side), or secondary tank bottom (non-interstitial side).

Page 24. The review also established that several tank operators use ER probes more than the coupons or other tools, because of the ease of data logging and analysis associated with the ER probes. Acknowledge that some operators were unable to retrieve ER probe data, as identified in responses (e.g., question 1, operator 2).

Page 24. Define the term “Effectiveness Threshold” to help readers understand its context and apply it. Also, it is so important that it might be worth adding one paragraph summarizing how it was determined, while continuing to cite Ph2 project

Page 25. “Mass-loss coupons were exposed to the **field sand samples in the laboratory conditions**; **the laboratory mass-loss coupons were acid cleaned and analyzed for material wastages** to determine surface average and deepest pit corrosion rates.” Clarify whether ASTM G1 was used for sample cleaning. In addition, what is the meaning of material wastages in this context? It could be drilling fluids or anything like that if there was a leak and the sample was exposed in the field. Would it be better to just use the term corrosion products?

Page 26. “UT-based mass-loss coupons were placed approximately three years prior to the placement of the mass-loss coupon assemblies.” Note that UT-based coupons were placed three years earlier for some, not all tanks, as supported by Table 4.1.

Pages 28 and 29. The characterization of the sand and its implications in the corrosion of steel should be discussed. Compare tank pad pH, sulfate, chloride, and phosphate concentrations with NACE SP0193 guidelines.

Page 30, Table 4-7. Clarify whether the pitting rate was calculated from the deepest pit using optical profilometry. Also, include the exposure times for lab (6 months) and field coupons (not clear) in all corrosion rate tables.

Page 31, Table 4-8. Could you please add the scale to be able to understand the images provided. The blue that could be seen in the field coupons might not represent the same depth as the same tone of blue since in the laboratory coupons and this information is important to make a clear comparison. I understand that it could be difficult to provide the legend for each picture given the space constraint. Nevertheless, a note can be added to inform that reader that all the information can be found in the appendices. Also, could you make sure that the west/east samples have not been inadvertently switched? It seems like the highest amount of corrosion damage is in the east side sand laboratory coupons, while this information is not reflected in the field coupon’s. Of course, there is a difference between lab and field conditions, but it is important to confirm.

Page 88. “The data in Figure 4-2 show that use of unbonded coupons is sufficient for monitoring sand pad corrosivity.” Is there a possibility to determine the accuracy of this based on the data that has been obtained? That would offer a more clear picture of how “sufficient” it is. In addition, it is important to mention that the pitting corrosion rate relationship is not as similar as the uniform corrosion rate data. In addition, a reasoning behind this behavior could be observed. It is known that when structures that are not connected to the CP system are in close proximity to it, they might interact with the system. Nevertheless, there is normally a location in the not connected structure through which the current comes out in the form of ionic transport, leading to localized corrosion, but that is not seen here. Is there a better explanation of what has been observed under these conditions?

Page 89. “The analysis of the field sand sample and corrosion rate data clearly demonstrate that the corrosion rates and not directly dependent of the bacteria concentrations.“ The data does not demonstrate that there is no direct dependence, what it demonstrates is that MIC is not the dominant corrosion mechanism. Nevertheless, the bacterias may be directly participating in the corrosion process. Please fix this sentence.

Page 90. “Sand electrolyte resistivity versus corrosion rate data is presented in Figure 4-5. The resistivity values of the various sand electrolyte samples ranged between 1,600 to 370,000 Ω-cm. The data in Figure 4-5 show that there is no direct correlation between the sand electrolyte resistivity and corrosion rates.” This statement made me think about the control of RH during this testing. Was the RH controlled at a value that would represent field testing? For instance, the RH could have been controlled to make sure that the electrolyte resistivity would stay the same as the value obtained when the sand that was characterized while being kept in a bag without interacting with the atmosphere. Or it could be completely saturated to follow the NACE SP0193 guidelines. If not, it is ok, but more information about the experiment conditions in the lab should be provided. Furthermore, there are instances when the resistivity is indicated as zero, but it might be more appropriate to write “negligible” or “not measurable”.

Page 91. “The corrosion rate data is for the six field tanks in which four sets of mass-loss coupons were placed on each tank. As seen in the figure, the corrosion rates positively correlate with the chloride plus nitrate for Tanks 2-4, and Tank 7.” This is a clever idea to represent the data, it will increase the significance of it if it is explained why the data from each tank was used as a subset. I believe the reasoning behind this is related to the complexity of the effect of the different parameters on the corrosivity of the soil and therefore, to keep other parameters as similar as possible, then the data for each tank was taken as a subset to evaluate the effect of the chloride plus nitrate concentration.

Page 91. “Two outliers are identified that caused the negative correlations. The Tank 5

outlier data point is marked by the dashed rectangle, and it occurred at the chloride plus nitrate

concentration of approximately 103 ppm. The Tank 6 outlier occurred near chloride plus nitrate

concentration of approximately 20 ppm.” Define the statistical method used to identify outliers (e.g., standard deviation, IQR).

Page 93. “It is concluded that at lower values of the chloride and nitrate concentrations, the field coupon corrosion rates are low and may not positively correlate with the chloride plus nitrate concentrations.” This could be related to the fact that nitrate in low quantities and in the absence of chloride can perform as a corrosion inhibitor.

Page 94. “floor scan of the plates” What was the technique used to scan the plates? Was it the UT test? Then, it is important to make it clear.

Page 95, Table 4-91. Please add at the bottom of the table the explanation for this way to represent the remaining thickness and the number of anomalies. Also, in terms of the CP data, include the meaning of U (unbonded) and B (bonded). It might be of interest in the future to measure the off and on potentials of the U samples to make sure there is no interference with the CP system. Please indicate the reference electrode that was used in the tables where there are potential values. Is there anything to add related to the CR that does not agree with the floor scan CR?

Page 96. What are the green and cyan dots and the blueish/purple lines in the floor maps presented in multiple figures after Figure 4-10? I noticed that it is explained all the way on page 149 and 150, but it should be explained at the first instance that this type of figure is presented in the report. In addition, the legend referent to the CP criterion (continue and discontinue red and green lines) is very confusing. Could you please modify it to something similar to “meets the XX criterion” and “does not meet the XX criterion”?

Page 97. “For the east and west locations, the tank plates on the floor scan did not have any anomalies. For the east location, the laboratory coupon corrosion rate data are judged to be closest to the floor plate, and for the west location, both laboratory and field coupon data are judged to be closest to the floor plate.” It is hard to understand the location of the laboratory coupon since the test was performed in the lab. Is this location related to the sand sample used for the lab test?

Page 97, Table 4-92. There are instances where there are no anomalies, but the CP system seems to meet the criteria for CP. It is important to discuss these discrepancies.

Page 98, Figure 4-11. What procedure was used to figure out if the anodes were active or inactive? I was able to figure it out in another section of the report. This information can be included in this page. For example, “see section XX”.

Page 99. “Both laboratory and field coupons did not experience extensive corrosion.” How do you define "Extensive corrosion", is there a certain value under which there is no extensive corrosion? Is this any reference for this?

Page 101. For the east location it is mentioned that “Both laboratory and field coupons did not experience extensive corrosion.” But, the laboratory DPCR is above 25 mpy. Similar statements were used from this point forward under similar situations. Please clarify.

Page 104. Revise language to ensure clarity and factual consistency with data. “Overall, the field coupons corrosion was more representative of the floor plate corrosion features near the sand sampling and coupon placement sites.”

Page 105. The text and the table information do not agree for the west location “For the west location on the tank plate 14-1, the floor scan detected seventeen anomalies: fifteen with remaining wall thickness of 0.200 inch,” The table shows 13 anomalies of 0.200 inch. There are mismatches between text and anomaly counts reported in tables. the reference electrode that was used

Page 106. Again, the text and the table information do not agree ”For the north location on the tank plate 2-2, the floor scan detected eight anomalies: three with remaining wall thickness of 0.205 inch, **three with remaining wall thickness of 0.200 inch**”

Page 112, Table 4-103. What is the difference in terms of chemistry, surface preparation and material processing between the field-mass loss coupons and the UT coupons? It does not make sense that for example the UT coupons have significant less pitting than the mass-loss field coupons.

Page 113, Table 4-103. Fix the tank numbers in the following sentence “UT coupons higher than the field coupons for Tanks 3015, 3359, 3018, 2247, and 1049”

Page 115. How is this Phased-array Based UT Monitoring, different from the UT-coupon technique?

Page 115, Table 4-104. Please provide information about the Chloride concentration and water content of the soil used for each tub.

Page 119, Tank 2. It is mentioned that “**The estimated inspection intervals varied between 0.8 to 28.3 years.**” and that “The estimated inspection intervals are compared to the values reported in API 653 inspection report for Tank 2, without tank bottom repair. The remaining wall thickness inspection threshold was 0.205 inch, **and the worst soil-side indication was 0.09 inch.** For the minimum remaining thickness of 0.1 inch, the API 653 inspection interval was less than 1 yr; the API 653 inspection interval estimate is consistent with values calculated using the field coupon data. T**his analysis highlights the value of targeted corrosion monitoring, and using the monitoring data to estimate the inspection intervals**.” It is always better to choose a conservative choice and therefore it is hard to feel comfortable with using the monitoring data when there is a lack of precision on the values obtained and there is a large range in terms of the estimated inspection intervals (**between 0.8 to 28.3 years**). We are comparing 1 year of inspection interval with up to 28.3 years. Furthermore, it is important to consider that the clean sand used during construction gets contaminated with the soil as time goes by capillary action (API 651) and diffusion.

Page 123. Provide technical justification for the recommended number of monitoring sites based on tank size. “It is suggested that tanks with bottom diameters less than 150 ft, at least four locations be selected for placement of the monitoring tools and for tanks with pad diameter between 150 to 250 ft, the monitoring locations should be at least eight or more.”

Page 123. One of the conclusions states that “Laboratory coupons appear to corrode less than the field coupons. This may be partly due to the temperature of the coupons. The field coupons could be at higher temperature (30-40 C) than the laboratory coupons which were under the laboratory ambient conditions of approximately 22 C.” Could this lower corrosion rate under laboratory conditions be also related to a lower RH present in the lab, which when it equilibrates with the soil leads to a reduced electrolyte resistance? This could also lead to a decrease in corrosion rate. In addition, the level of sand compaction can influence the availability of oxygen, affecting the cathodic kinetics. The lower the oxygen concentration the bottom tank corrosion would decrease. Please discuss potential impacts of lab RH and oxygen availability. In addition, consider sand compaction effects on cathodic kinetics.

Page 123. One of the conclusions says “Aerobic bacteria presence is dominant in the sand samples. However, there is no direct correlation between the presence of bacteria and coupon corrosion rates; this”. Nevertheless, it is hard to make a correlation when there are so many parameters not being controlled when doing the comparison. Elaborate on limitations in establishing a correlation between microbial presence and corrosion.

Page 124. In this statement “A detailed analysis of the UT-based mass-loss coupon technology indicated that pitting corrosion analysis qualitatively matched with the visual observations.” it is important to provide a more detailed analysis. Expand on the qualitative match between pitting corrosion observations and UT data.

Page 124. “An analysis of the tank bottom indications and field coupons corrosion rate indicated that field coupons generally provide level of information that commensurate with the tank bottom

anomaly corrosion rates.” Would it be possible to quantitatively specify in what percent of the cases this is true?

Page 124. “Overall, it is determined that use of field coupons and determination of chloride plus nitrate concentration are expected to provide a reasonable assessment of the tank pad corrosivity to the tank operators. Tank operators can supplement the tank pad corrosivity assessment by including measurements of the bacteria concentrations to assess MIC risk, resistivity, and other anion species such as sulphate etc.” Is there a possibility to suggest additional measurable parameters for corrosion assessment beyond those studied?

Page 127. Were the criteria for CP effectiveness considering a CR below 5 mpy disregarding the number of corrosion soil side indications based on the load bearing capacity of the tank bottom? I ask this question because if there are many sites where there is corrosion in the soil side, it will be important to consider the load bearing capacity of the structure as a whole since these different sites will be stress concentrators and their strain/stress fields will interact/affect each other. I know there are guidelines for this in API 653. But, could a large number of corrosion spots lead to a different interpretation of the results from the point of view of mechanics of solids?

Page 128. “The polarized potential data was obtained by calculating the difference between the instantoff potentials and native potential.” Confirm if the intended term is “polarization decay” per NACE SP0193, and revise the report if necessary.

Page 141. Correct typo in tank count statement “Of these, CP systems were found to have effectively mitigated soil-side corrosion on sixty-seven (113) tanks.”

Page 143. Parts of the information presented in the first paragraph of section 5.1.2. do not match with the data presented on Table 5-3. Ensure alignment between textual analysis and figures/tables. The same happens at the end of the page. Here is one example “Regarding the instant-off potential evaluation, most tanks with questionable CP effectiveness fall in the category of instant-off potential being sometimes yes, followed by the tanks in the mostly yes category.” See figure 5-4(a). And here “Regarding the polarized potential evaluation, most tanks with CP effectiveness questionable fell in the category no data, followed by the tanks in the category of polarized potential being yes. The tanks in the category of mostly yes data rank third.” Something worth analyzing is that generally when the 100 mV criteria is met, the -850 mV criteria is met, but it is not what is being observed in this project.

Page 145. The same disagreement between text and figure takes place for this statement “there are four tanks in the no data category and one tank in the yes category.”

Page 146. Again “As seen in Figure 5-7(a), there are seven tanks in the mostly yes category, one tank each in the sometimes yes and mostly no categories, and four tanks in the no data category;”

Page 148. For each of the tanks for which the CP data is being analyzed, the first paragraph indicates the number of soil-side corrosion indications and that they are below the threshold. Specify the standard used to define the corrosion indication threshold (100, 500?).

Page 148. Table 5-4. In three columns the symbol “>=” is being used, such as in “# IRF

Potentials ≥ -0.850” this would be met for any potential above -850 mV which would be any value more positive than -850 mV. Is that what is meant here? I believe that the authors are trying to express the opposite, which implies that there is cathodic protection. Confirm correct usage of “≥” in context of -0.850 V criterion; likely intended to be “≤”.

Page 150. The sentences say”It was noticed that two zones of bottom plates did not experience sol-side corrosion. The two zones are marked by purple zig-zag lines in Figure 5-9.” do not agree with the figure. Some of the zones have green dots and there are three zones. Revise sentences describing purple zig-zag zones to align with the figure.

Page 150. It is being mentioned that “The polarized potentials measured at the perimeter met the 100-mV criterion.”, but the figure does not agree with this statement.

Page 151. In this part, “The 2021 instant-off potentials measured through the profile tubes only met the -0.850 V criterion towards the center of the tank. It is not clear why the instant-off potentials did not meet the criterion when the CP current density was adequate.”, could you please elaborate more on how do you define an adequate current density? NACE SP0193 does not provide this criterion, now NACE SP0169 does. If you are using the latter standard since there is not a current density criterion for AST then please state it. Or, are you comparing the field value with the design current density? This information is also on the table for tank 101. The same was done for Tank 102 and in other instances (page 151, text and table).

Page 162. In different previous cases the distance from the perimeters where corrosion occurs was not accurate, but for tank 104, the error is significant. This tank has the biggest bottom plate soil-side surface area without corrosion, but the statement is the same “Most of the corrosion occurred within 20-30 ft from the perimeter of the tank.” Please improve the information provided for each tank in section 5.

Page 170. Again, it is important to elaborate more about the “adequate CP current”. What is it? How is it defined? “Adequate CP current density did not correlate with the distribution of the soil-side corrosion indications, indicating that there are other factors, not considered in this study, that could influence soil-side corrosion.”

Page 170, Table 5-17. How was the sandpad resistivity measured? It is important to note the effect of RH on the moisture content of the sand, which leads to changes in its resistivity. If the measurement conditions were not controlled that could lead to the variations that can be observed in the locations.

Page 17, Table 5-18. There is an error since the figure does not show information for unsaturated sand. Also, looking at the figure, I would have expected the corrosion rate of the saturated sand to be higher (or lower Rp) than that for the unsaturated sand because of the fact that the electrical resistance should decrease, but at the same time the more water there is would lead to a dilution of the electrolyte in the sand, reducing the chloride concentration. Please elaborate more since the text does not mention what saturated and unsaturated terms mean or how the conditions were controlled.

Page 176, figure 5-22. The units for soil resistivity are missing. Same for figure 5-23.

Page 183. Fix this sentence “These two simulation results sho99999wed that combination of pad thickness variation and sand corrosivity could result in diminished current distribution.”

Page 183. “A detailed analysis of Tank 101 with a well-designed CP system provided some insight regarding caused for CP being insufficient. The tank pad corrosivity in combination with the tank pad thickness variation could limit the CP ability to adequately saturate the tank bottom with sufficient CP current needed for protection. It was observed even the well-designed CP may not be sufficient in mitigating soil-side corrosion if the civil and construction conditions for the tank pad deviated from the designed values”. It may be helpful to revisit the applicability of the -850 mV and 100 mV polarization decay criteria in such contexts. There are scenarios where these criteria are met, yet corrosion indications persist, and vice versa. This could point to a need for improved measurement practices or adjusted evaluation criteria, especially in environments with potential microbial influence. Notably, instances such as Tank 106 suggest a discrepancy between protection assessment based on standard criteria and actual corrosion observations. These findings emphasize the importance of complementing standard criteria with additional diagnostic tools and possibly revising assumptions where warranted.

Page 185. Was the sand used in the VCI lab experiments extracted from the sand pad? What was the chloride and sulfate concentration used for the experiments? How was the amount of water and chloride/sulfates to be added determined?

Page 186, Table 6-2. It seems like the sand was not completely removed and new sand was not used for this project. In unit 1 the VCI was allowed to escape and then DI water was added, but, was the concentration of VCI, chloride and sulfate measured in the stream of water coming out to make sure that everything was reset? In other words, What measures were in place to make sure that the conditions for each testing vessel were reset and also the same between units 1 and 2? This is important to make sure that the comparison between the vessels, which for this project were loaded with different VCIs, would lead to a fair comparison and that the testing conditions are completely known to understand the results. Also, please confirm the notes for unit 2 saying “Last VCI injection on the reassembled experiment on 4/23/2024”. I also noticed that the information in this Table disagrees with the information in Table 6-8 for experiment 2. This latter table implies injection of VCIA during the first injection and then injection of VCIB for the second injection.

Page 188, Table 6-4. What is the reason behind setting up the concentration of chlorides and sulfates to different values compared to units 1 and 2. Please elaborate. In addition, please correct the notes for unit 3. There are errors in the year and incomplete sentences.

Page 188. The moisture content for units 3 and 4 was controlled and set to 50%, is this representative of field conditions? What are its implications on the results obtained in this work?

Page 189. The moisture content for the large scale experiments was set to 75%, but it was left open to the atmosphere and therefore it would equilibrate with the lab RH which is normally about 50% potentially drying the soil and creating fluctuations depending on the effect of diurnal cycles and seasons on the lab conditions. Would these conditions be similar to the ones found in the field?

Page 193, Figure 6-5. Was the electrode in the ER probe used for the PRCI Phase 2 characterized? Did it exhibit localized corrosion or uniform corrosion? If it had uniform corrosion it is ok to use it for this project, which is what I think was done since the same metal loss value is reported, but it is important to note it. In addition, if the electrode was exposed to another VCI its oxide film would have some residue from it. Furthermore, the behavior of an already corroded metal is different from a pristine one. And in between the end of the previous project and the start of this one the material loss is the same, how can this happen? Discuss about this in the report. Another important information that can help understand the experiment is how was the washing of the sand evaluated to make sure that there is no VCI residual from PRCI phase 2. I expect that the chemical can get absorbed on any solid material and stay attached. It could be washed away with water, but there will be a residual remaining. Please provide information about this washing step that was performed between experiments and how was it evaluated to know when to stop.

Page 193. It is stated that “The reinjection interval is estimated to be 6 months based on Exp1Probe 2 corrosion criterion being 2.5 mpy.” Is there a standard that establishes this criterion? NACE SP 21412 provides guidelines mentioning that the interval should be selected based on environmental conditions, VCI type and longevity, and Corrosion monitoring data. It also mentions that corrosion rates below 1–2 mpy are often considered acceptable in well-controlled environments. If that latter information is being used, it is important to be careful and not to categorize it as a criterion to avoid the reader assuming it to be a criterion. Also, it was noticed that the plots y axis title should be changed to thickness loss. At the moment of injection the plot reports 5 mils, but when the project started it reports 2.5 mils approximately. The exposure period under the start and the first VCI injection in this project is 0.6 years. Calculating the corrosion rate is not as straightforward since the ER electrode at the beginning of this project was not pristine. Please consider using these facts in the analysis.

Page 195, Table 6-7. In the last row the statement in the note needs to be improved. It does not read well.

Page 195. “The Experiment 2 was disassembled, and ammonium ion concentrations were measured in the pore water of the Experiment 2 sand, it was found to be approximately 10 ppm. The Experiment 2 sand was dried till the dissolve ammonium ion concentration was close to 2 ppm or below.” Please describe the reasoning behind these actions for the reader to understand the testing better. Ammonium can affect steel corrosion in different ways depending on its concentration and the presence of chlorides. Also Table 6.8 at exposure time of 2.78 years mentioned that the sand was dried out to reduce the VCI concentration, which disagrees with the statement highlighted in this comment unless the VCI contained ammonium. Please clarify.

It was noticed that sand samples were extracted from experiment 1 and 2? Was the sand characterized?

Page 197, Figure 6-8. Where the ER electrodes used pristine? They have lower thickness loss than the values reported in the previous figure where it was decided to dry the sand.

Page 200. The paragraph includes these two sentences that do not agree with each other “Experiment 3 was conducted to understand VCI migration in the cone-up tank pad configurations, **this experiment was started under this project**…The **timespan on the x-axis in Figure 6-10 covers both PRCI Phase 2 and this project**.” Please clarify, was the ER probe used in a previous project? The same happens for Experiment 4 (page 204).

I understand that experiments 1 and 2 are related to the determination of interval reinjection and 3 and 4 are related to VCI migration. But, between 1 and 2 the experiments are different not just on the VCI used for injections, but also on the moisture content. In terms of 3 and 4 the VCI used and also the inclination of the setup are different as well. It is hard to understand the reason behind the experimental methodology chosen. Could you please elaborate more about it in the appropriate section? Or perhaps there is a typo on page 203? It states that “The cove-up tank pads have gradients of approximately **1-2 inch/10ft**” vs on page 204 for experiment 4 it mentions “**6-8 inch/10 ft**.”

Page 202. There is a typo in “The Experiment 1 ER probe data are used to estimate the corrosion rates between various time instances.” IT should be experiment 3. The same happens in page 206 for experiment 4.

Was the data for mass loss and UT coupons analyzed for Experiments 1-4? I only observed the ER probe data in the report.

Tables 6-14, and 6-15 and Figures 6-16 and 6-18 are not discussed in the text. Please provide an analysis of the data presented.

Page 213. Considering the behavior after VCI injection, the ER probe data provided at 15ft shows an increment in corrosion rate right after injection. It is known that the VCI needs time to diffuse, but this is a very similar behavior than the one seen at 20 ft and both are different from the behavior at 10 ft. Therefore, could you please elaborate more on how the dispersion range is defined?

Page 216. The information presented is very important in the field and there is great impact and significance in the results obtained and their analysis. But, it is important to point out that these are the results obtained under the conditions that were chosen for the test that may not be exactly the same as the field conditions. Some of the tests were done with sand that was reused from other projects that had different conditions and where possibly other VCIs were used and there could be a residue. But, it is known that obtaining sand from the field is very expensive as well. In addition, some of the ER probes seem to be used in a previous project and therefore the test was probably not done with pristine electrodes, which modifies the corrosion rates and makes it difficult to make a comparison between testing. In addition, these electrodes could have residues from the different projects. If this is not the case, please clarify in the document. Furthermore, the limitations of a laboratory scenario limit the conditions under which the testing was performed. Specifically, the moisture content and the RH at the test environment can affect the corrosion rates and the diffusion of the VCI in the test. Therefore, it is important to discuss the differences between the field and lab conditions. This will be important to understand how these results could be extrapolated to the field while also considering its limitations.

Page 409, Figure A-114. Consider revising the source for this plot since the values do not make sense. Verify units and signal integrity in voltage data; consider potential measurement setup issues.

The observations made in this revision should be considered in the conclusion section of this report. A key point needs to be highlighted in the conclusions... It may be helpful to revisit the applicability of the -850 mV and 100 mV polarization decay criteria for when CP is applied to the bottom of ASTs. This report shows that there are scenarios where these criteria are met, yet corrosion indications persist, and vice versa. This could point to a need for improved measurement practices or adjusted evaluation criteria, especially in environments with potential microbial influence. Notably, instances such as Tank 106 suggest a discrepancy between protection assessment based on standard criteria and actual corrosion observations. These findings emphasize the importance of complementing standard criteria with additional diagnostic tools and possibly revising assumptions where warranted.

In the future, it might be worth also recording the location and environmental conditions at the test site. For example a large amount of precipitation can decrease the soil electrolyte resistivity and allow for corrosion rate to increase or being close to the sea might provide soil richer in chlorides.