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Effects of Corrosion and Wildfires on Galvanized Steel Towers: A Case Study with Wildfire and Corrosion Sensors

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ABSTRACT

With the rising prevalence of climate change, utilities are facing increased risk and consequences from accelerated corrosion and wildfires, particularly in the state of California and British Columbia. These fires have the potential to compromise the integrity of galvanized steel lattice towers, widely used in high voltage transmission lines. Considering this, it is crucial for utilities to assess the potential risks and deploy corrosion control and postfire inspection strategies. This paper investigates the effects of corrosion and wildfires on these structures and presents a case study involving real-time monitoring sensors for early risk identification and evaluation. This paper aims to shed light on the challenges posed by wildfires and corrosion to utility structures and provides actionable insights for future preparedness. With escalating concerns about climate change, utilities must adapt their strategies for a more resilient future.

Keywords: Corrosion, wildfires, climate change, utilities, galvanized steel lattice towers, postfire inspection, real-time monitoring, case study, California.

INTRODUCTION

In recent years, climate change has caused a significant increase in the frequency and intensity of wildfires and corrosion, particularly in California. These occurrences pose a severe threat to utility structures, primarily high voltage transmission lines supported by galvanized steel lattice towers. Traditionally, these towers have been considered resilient to corrosion and wildfires due to their steel construction. However, recent observations indicate that exposure to corrosion and high-intensity wildfires can compromise the towers' structural integrity, leading to reduced service reliability and increased restoration costs.

Corrosion in transmission lines is a significant concern for the electric utility industry, especially when these lines are installed in corrosive soils. This is an issue that affects both the reliability and the lifespan of power transmission infrastructure. Corrosion is a natural process where metals deteriorate due to chemical reactions with their environment. In the case of transmission lines, the buried portions are particularly vulnerable to corrosive soil conditions. Several factors contribute to this issue.

Wildfires and fires in general can have a significant impact on the corrosion of galvanized towers, as well as broader environmental effects, from a corrosion standpoint. Below are some key considerations:

<u>Effects on Corrosion of Galvanized Towers</u>

- Increased Temperature: The high temperatures associated with wildfires can compromise the integrity of the galvanized coating, making the underlying metal more susceptible to corrosion. Figure 1 shows the wildfire exposed tower under study and Figures 2 and 3 exhibit the effect of wildfires on galvanized layer the first defense against corrosion in transmission towers[1],
- Accelerated Oxidation: Hot environments can accelerate the oxidation process. When the protective zinc layer is compromised, the underlying steel is exposed and more likely to corrode.
- Chemical Exposure: Wildfires can produce corrosive by-products like ash and soot, which can deposit on tower surfaces. These substances may contain chemicals that are corrosive and can speed up the deterioration process.
- Atmospheric Changes: The heat and chemical changes in the atmosphere around wildfires can alter local humidity and moisture levels. Moist conditions can serve as a catalyst for corrosion.
- Physical Damage: The physical impact of a wildfire can also strip away protective layers, making the metal more exposed and thereby accelerating corrosion.
- Soil Chemistry: Wildfires can alter the chemistry of the soil where the tower is anchored, which may have corrosive properties and thus affect the base of the structure.

<u>Environmental Impacts from a Corrosion Perspective</u>

- Material Failure: As towers corrode, the risk of material failure increases. This could result in falling debris that could harm local flora and fauna or contaminate water supplies.
- Toxicity: As the metal corrodes, it can release harmful substances into the environment. For example, zinc and iron ions can be toxic to aquatic life.
- Infrastructure Weakness: A corroded tower is a weakened structure that poses risks not only to itself but also to other connected infrastructure. If one part of a network fails, it could have a domino effect.
- Resource Drain: Repairing or replacing corroded towers is resource-intensive, which indirectly impacts the environment through the extraction, manufacturing, and transportation of new materials.
- Waste Generation: Corroded materials often end up as waste unless they can be effectively recycled, adding to landfill problems and associated environmental impacts.
- Energy Costs: Monitoring and maintaining corroded structures require energy, contributing to the overall carbon footprint.

Figure 4 shows a corrosion crew performing corrosion risk assessment in a substation. Figures 5(a) and 5(b) show transmission tower legs exhibiting signs of microbiological corrosion. Figure 6 is a galvanized anchor bolt under a base plate for a communication tower exhibiting accelerated corrosion and extensive thickness loss. Figure 7 shows internal corrosion of a substation aging galvanized pole on concrete foundation. The measurement of corrosion potential will indicate the corrosion activity on galvanized members, as seen in Figure 8.

Understanding the link between wildfires and corrosion is essential for effective management and mitigation strategies. By taking proactive measures, it's possible to reduce both the corrosion risks and the broader environmental impacts.

Implications for the Electric Utility Industry

There are four critical implications of this corrosion and wildfire for the electric utility industry transmission structures, as described below.[2,3]

- Service Interruptions: Corrosion can lead to weakened structures, posing a risk of catastrophic failure, which in turn results in service interruptions.
- Higher Maintenance Costs: Constant monitoring and maintenance are required to keep the infrastructure in working condition, adding to the operational costs.
- Reduced Lifespan: Corrosion can significantly shorten the lifespan of transmission lines, necessitating earlier replacements.
- Safety Risks: Weakened structures due to corrosion can pose serious safety risks, including the possibility of electrocution or fire.

Mitigation Strategies

Several readily implementable strategies to mitigate to varying degrees the corrosion related to wildfire and in general corrosion of electric utility transmission structures[3].

- Material Selection: Use of corrosion-resistant materials, such as certain alloys or coatings, can help reduce the rate of corrosion.
- Cathodic Protection: This is an electrochemical method used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell.
- Monitoring Systems: Advanced sensors and monitoring systems can be used to track the condition of the transmission lines and predict when maintenance is due.
- Soil Treatment: Modifying the soil to reduce its corrosivity can sometimes be an option, though it is generally more challenging and less common than other methods.
- Engineering Design: Special designs, such as raising the infrastructure above ground or using non-metallic materials, can also help mitigate risks.
- Monitoring by wireless corrosion sensors and Regular Inspection and Maintenance: Periodic checks and preemptive replacements can prevent unexpected failures and service interruptions.

Understanding the risks and implementing appropriate mitigation strategies is crucial for the electric utility industry to ensure reliable and safe power transmission, especially in regions where wildfires and corrosive soils are prevalent.[1] Utilizing electrochemical inspection methods and quantification of corrosion risks is vital for condition assessment.[4]

By adopting a comprehensive approach to understanding and combating corrosion by cathodic protection[5] and by wireless sensors the electric utility and communication tower industry can improve the reliability and longevity of its infrastructure.

Wildfires and Climate Change

Climate change has had a profound effect on the frequency and intensity of wildfires in California and Hawaii. Between 2017 and 2023, the largest wildfires occurred, burning over 10.07 million acres and destroying many thousand structures.[1] The changing climatic patterns and dry conditions have exacerbated this, making it imperative for utilities to adopt innovative strategies to mitigate these effects.

Steel Towers and Wildfires

Lattice steel towers are commonly used in high-voltage transmission lines due to their high strength-to-weight ratio. While these structures generally survive wildfires, extreme heat exposure can cause unseen damage to the metallurgical characteristics and reduce the structural strength. Therefore, utilities must develop robust postfire inspection programs to evaluate the condition of these towers.

CASE STUDY - CORROSION/WILDFIRE SENSORS: USE OF SENSORS IN HAWAII

Two years ago, the authors installed temperature/corrosion sensors at two client site locations in Hawaii. The initiative aimed to demonstrate the critical role these sensors play in real-time monitoring, thereby allowing the client to take immediate corrective actions. Figure 9 shows a schematic of the sensor system the Data from these sensors are transmitted via satellite for timely assessment.

Benefits

The temperature/corrosion sensors benefit the client in two important ways.

- Risk Identification: They aid in recognizing sites at high risk due to factors like extreme temperatures, wildfires, storms, or accelerated corrosion.

- Timely Intervention: The early detection allows maintenance teams to respond quickly, minimizing risks of mechanical failure or catastrophic events.

Case History

On September 13th, 2023, the wildfire/corrosion sensors detected rapidly increasing temperatures and signs of accelerated corrosion at a site. This data was promptly relayed to the client's senior management for immediate action. Graphs and photos documenting these changes are provided in Figures 10 through 12. You can look at the live view webcam at the volcano (note: camera is facing east, where the sensor is installed 3.61 miles away at Webcams - Hawaiʻi Volcanoes National Park (U.S. National Park Service) (nps.gov).

Discussion

It should be noted that temperatures exceeding 200℃ or 392℉ can compromise the structural integrity of galvanized steel transmission towers, causing galvanizing layers to delaminate and degrade.[1] Higher temperatures will result in melting of galvanized layer and still higher temperatures above 600℃ or 1112℉ will result in loss of strength. This is why it is important to know the temperature of exposure. Figure 14 shows melted zinc resulting from high temperature exposure. Table 1 presents the structural impacts of the elevated temperatures on galvanized steel towers.[1]

Table 1: Structural impacts of the elevated temperatures on galvanized steel towers.[1]

Temperature	Structural Impact
>200℃ or 392℉	Decrease in modulus of elasticity.
>400℃ or 752℉	Decrease in yield strength and zinc will begin to melt.
>600℃ or 1112℉	50% loss in strength and oxidation will occur.

The EnviroZensor exhibited temperature rise to 200℃ or 393℉ as a function of time as shown in the plot attached to this paper. The raise in temperature did not have structural impact and no melting or deformation was observed at the site confirming the sensor readings that exposed temperature did not exceed 200-230℃ range. However, the corrosion potential shifted to a more active range indicating corrosion activity is occurring due to temperature raise.

About the recent Hawaii wildfire, we believe that the temperature rise was not due to direct lava exposure and could be attributed to the underground movement of lava in that area. There does not appear to be anything above ground which would cause the temperature rise - no fires or active lava flows near the area. The area where the tower is located was inundated in 2018 by a lava flow in the Puna area. Thus, active underground lava tubes exist in the area. With the recent eruption of Kilauea, lava could be flowing in the underground lava tubes thus causing a rise in the ground temperature. Also, the tower is located near the Puna Geothermal facility. This would indicate that there is geothermal activity in the area.

The absence of corrosion and wildfire monitoring technology could result in significant asset loss, especially since there are sensors available in providing condition data even at extreme temperatures above 1,093℃ or 2,000°F prior, during and after wildfires and accelerated corrosion. Please see Figures 11 through 13 the data transmitted by the sensor for a more detailed understanding of these events.

The electrochemical potentials serve as indicators of corrosion activity. By measuring the potentials near underground metallic assets, the IR drop caused by soil can be reduced. In this case, a reference electrode was installed next to a galvanized pole or a grounding copper at a tower site near the volcano. The resulting potential readings were then transferred to the corrosion engineer for analysis. The second plot Figure 12 clearly shows the change in mixed potentials, which is a direct effect of the temperature rise caused by the presence of lava in the lava tube. This increase in temperature leads to a change in the corrosion potentials and the formation of corrosion products. For galvanized assets, these readings suggest accelerated corrosion and a loss in galvanized layer thickness. All of these measurements, including temperatures reaching up to 220 degrees Celsius and potential readings, were performed using the sensor and were analyzed by the corrosion engineer in charge. He looked for critical values that indicate unacceptable risks from a corrosion engineering perspective. This case study indicated the sensor exhibited a raise in temperature due to lava flow. However, the temperature did not reach to level that had structural impact and no significant depletion of zinc or deformation of steel was observed. Corrosion data however indicated change in corrosion activity and formation corrosion products that shifted the mixed potential to more active potentials.

Conclusions and Recommendations

The EnviroZensor exhibited temperature rise to 200℃ or 393℉ as a function of time as shown in the plot attached to this paper. The raise in temperature did not have structural impact and no melting or deformation was observed at the site confirming the sensor readings that exposed temperature did not exceed 200-230℃ range. However, the corrosion potential shifted to a more active range indicating corrosion activity is occurring due to temperature raise.

Remote sensors could be installed on structures throughout a pole/tower service areas to provide real-time environmental temperature information. This system of sensors could provide immediate alerts when a wildfire is present and could provide the temperatures to which the structures are exposed. Depending on the temperatures to which a structure has been exposed, a utility may be able to determine the level of possible metallurgical damage to the structure. In addition to monitoring for wildfires, the remote sensors could also monitor and provide an assessment of the corrosion activity at the structure.

For aging structures, the effect of corrosion is a concern. To fulfill this purpose, a sensor should be capable of real-time transmission via satellite, providing the temperature of the environment where the structure is located as well as corrosion potential data in both atmospheric and soil environments. This information is crucial for identifying the risks associated with structures exposed to wildfires and corrosive conditions.

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REFERENCES

1. M. Zamanzadeh, G. Bayer, P. Taheri, A. Kumar Chikkam and Clinton Char: Wildfire Impacts on Power Industry Steel Structures-Parts 1, and 2." Materials Performance, February, 2023.

2. M. Zamanzadeh and Jackson: Corrosion Risk Strategies for Below-Grade Foundations of Transmission and Distribution Structures-Parts 1, and 2." Materials Performance, April 2014.

3. M. Zamanzadeh, C. Kempkes, D. Aichinger and D. Riley, "Laboratory and Field Corrosion Investigation of Galvanized Utility Poles." ASCE Electric Transmission Conference, Oct 17, 2006.

4. AMPP SP0415 Std. 1895, "AMPP/IEEE Joint Standard Practice for Below Grade Inspection and Assessment of Corrosion on Steel Transmission, Distribution and Substation Structures "(Houston, TX: AMPP, 2015).

5. P. Taheri, M. Zamanzadeh, "Galvanic Cathodic Protection for Power Transmission Tower Grillage Foundations," Materials Performance 55 [12] (2016): p. 2

6. P. Taheri, A. Mansouri, B. Bachour, N. Ahuja, M. Zamanzadeh, "Inspection and Mitigation of Underground Corrosion at Anchor Shafts of Telecommunication Towers," CORROSION 2017, paper no. 8898 (Houston, TX: NACE, 2017).

Figure 1: Tower exposed to wildfire under study.

Figure 2: Cross sections of galvanized members exposed to wildfire and the damage observed indicating oxidation and delamination of galvanized layer due to temperature raise above 350F (177℃)[1].

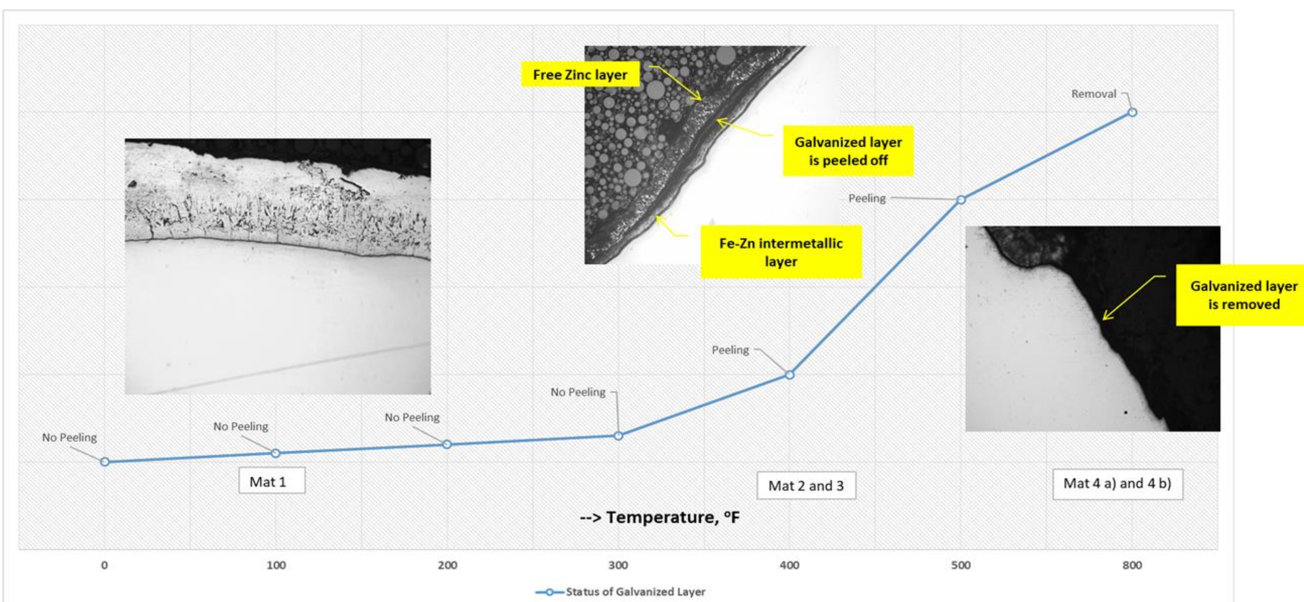

Figure 3: Temperature versus galvanized layer peeling indicating temperature raise above 300 F (149℃) results in delamination and depletion of galvanized layer[1].

Figure 4: Corrosion crew performing corrosion risk assessment in a substation.

Figure 5 a): Corrosion Perforation in Corrosive Water

Figure 5 (b): Tower legs exhibiting signs of microbiological corrosion.

Figure 6: A galvanized anchor bolt under a base plate for a communication tower exhibiting accelerated corrosion and extensive thickness loss.

Figure 7: Internal corrosion of a substation aging galvanized pole on concrete foundation.

Figure 8: Measurement of corrosion potential will indicate the corrosion activity on galvanized members.

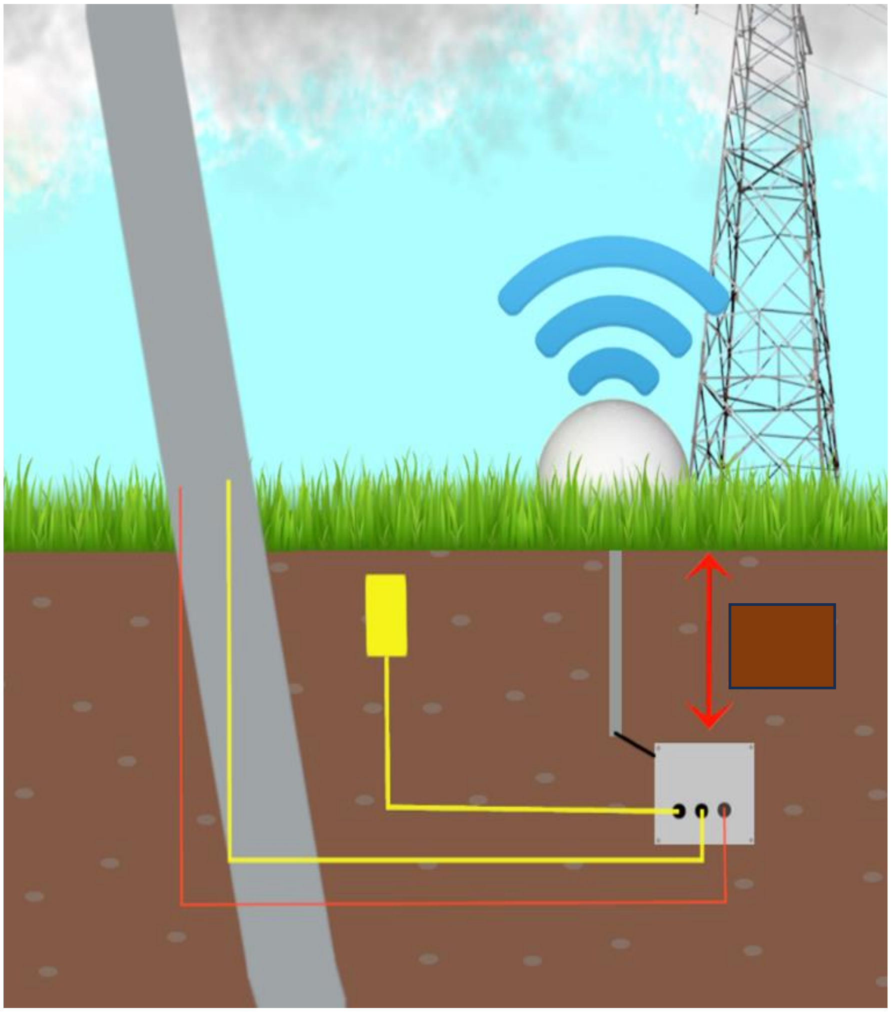

Figure 9: A corrosion wildfire sensor transmitting corrosion and temperature data to WebView on time to provide warnings.

Figure 10: Rapid rise in temperature detected by sensor EnviroZense on September 13, 2023.

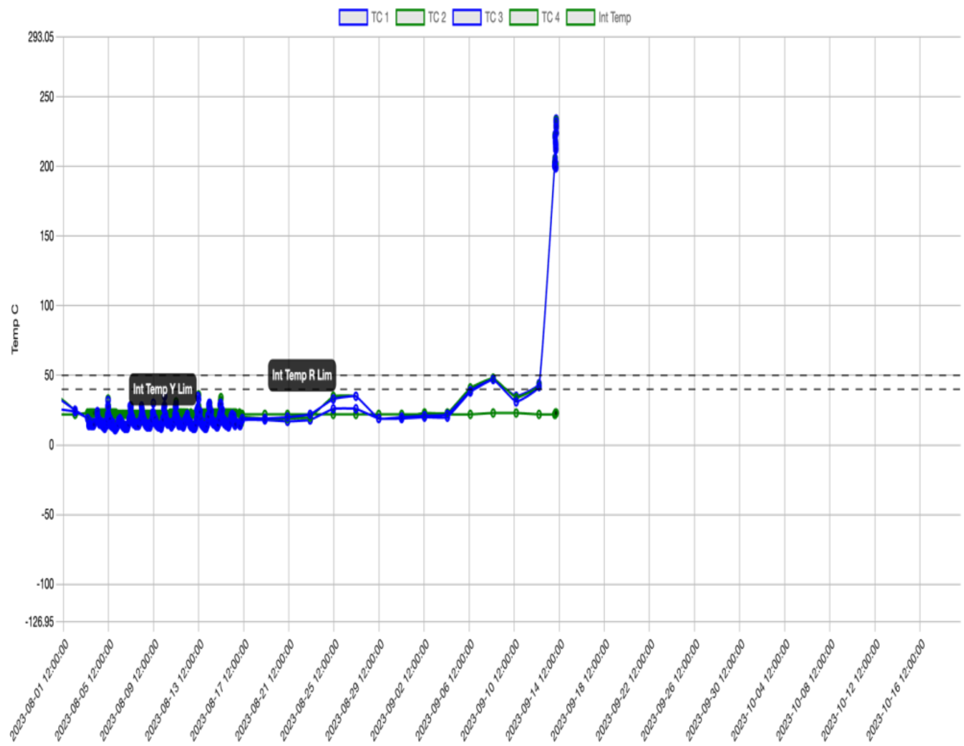

Figure 11: Raise in temperature over 380 F (193℃) due to lava flow underground.

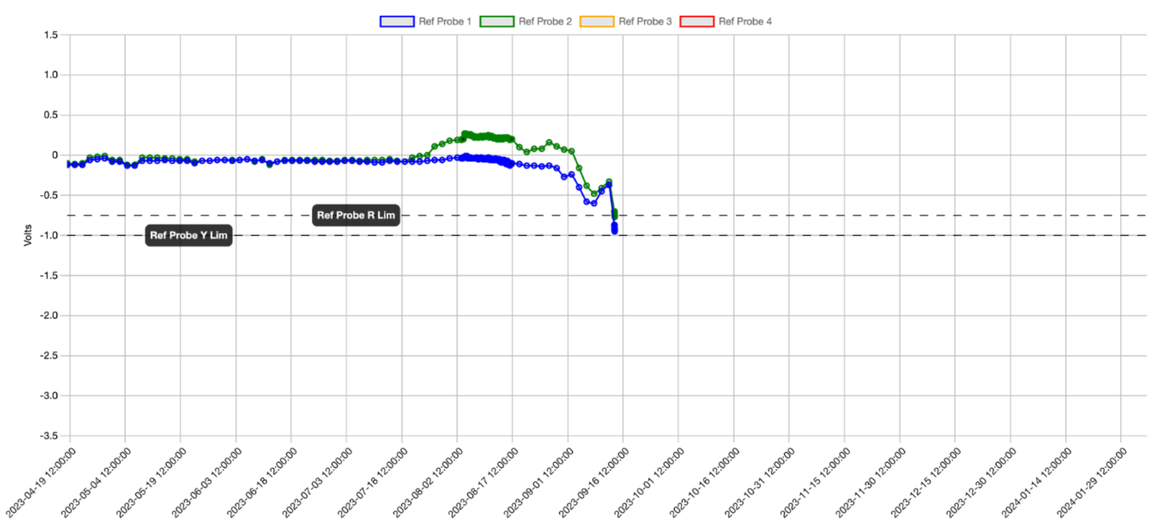

Figure 12: Rapid rise in corrosion activity detected by sensor (EnviroZense) on September 13, 2023.

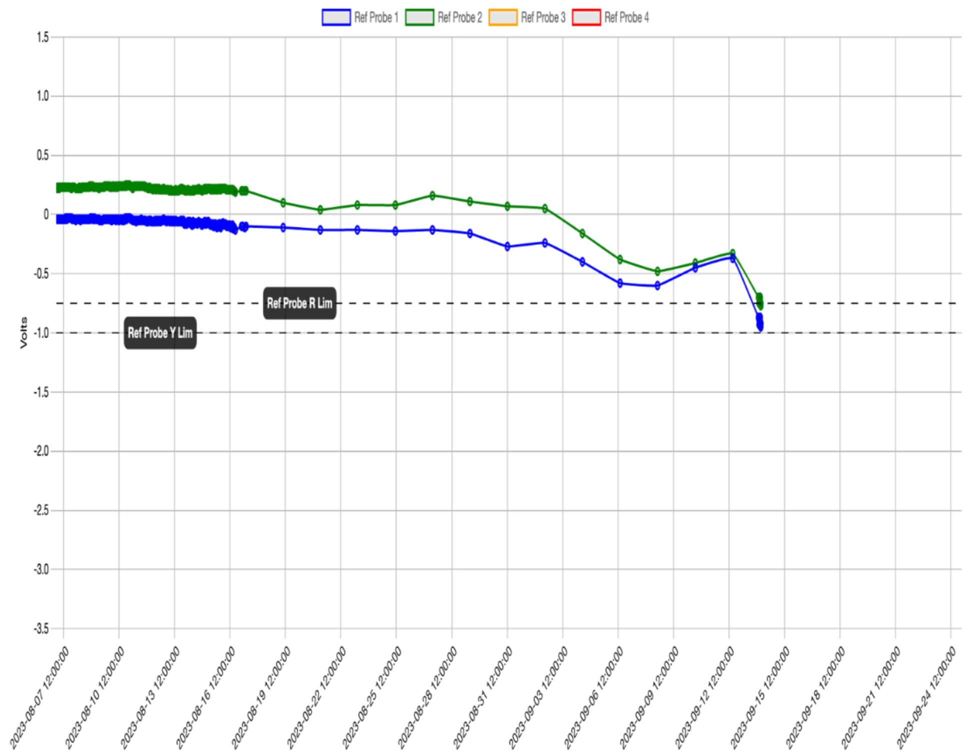

Figure 13: Rapid rise in corrosion activity (Blue and Green plots) detected by sensor on September 13, 2023

Figure 14: In another case zinc was observed due to high temperature exposure above 850 F (454℃). No such melting observed in this case.