
Corrosion Rate Analysis and Remaining Life Assessment of Atmospheric Hydrocarbon Storage Tank in Petroleum Processing Facilities

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Article Info

Article history:

Received May 31, 2026

Revised May 31, 2026

Accepted June 01, 2026

Published June 01, 2026

Keywords:

Corrosion rate

Remaining life assessment

Risk based inspection

Root cause analysis

ABSTRACT

This study was conducted to analyze the corrosion rate and Remaining Life Assessment (RLA) of an atmospheric storage tank in a petroleum processing facility using Ultrasonic Thickness Meter (UTM) measurement data. The analysis was complemented by a Root Cause Analysis (RCA) employing the Ishikawa Fishbone Diagram approach and a Risk-Based Inspection (RBI) evaluation to provide optimal inspection recommendations. Based on the calculation results, the tank has been in service since 1984; however, its structural condition remains within an acceptable and safe operating range. The RCA results indicate that corrosion on the tank shell is caused by a combination of technical and non-technical factors. The calculated risk level places the tank in the medium-risk category. Overall, the structural integrity of the tank can still be considered suitable for continued operation.

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INTRODUCTION

The oil and gas industry plays a vital role in ensuring national energy security; therefore, the reliability and continuity of process and storage equipment operations must be maintained effectively (Jaluakbar & Putra, 2019; Maharani & Akbar, 2023). One of the key pieces of equipment in production facilities and refineries is the storage tank, which serves to store fuel and petroleum products. During its service life, a storage tank is highly susceptible to material degradation caused by corrosion, particularly in the bottom plate and lower shell sections that are continuously exposed to stored fluids and condensate (Al Ameri et al., 2023; Davis, 2000; Shokrzadeh & Sohrabi, 2016).

Corrosion is one of the primary causes of equipment reliability degradation in the oil and gas industry. The corrosion process can lead to wall thickness reduction, thereby compromising the structural integrity of storage tanks and increasing the risk of leakage (Fontana, 2005). If not monitored regularly, corrosion-related failures can result in significant economic losses, environmental

contamination, and even potential fire hazards (Banuta & Tarquini, 2010; Godoy et al., 2022; Njomane & Telukdarie, 2018). Therefore, periodic inspection and equipment integrity assessment are essential to ensure that the storage tank remains within safe operating limits throughout its service life.

One of the methods commonly used to monitor thickness reduction caused by corrosion is the Ultrasonic Thickness Meter (UTM). This non-destructive testing (NDT) technique enables the measurement of the actual wall thickness without causing damage to the component (ASM International, 2002; Mihaljević et al., 2019). Thickness measurement data can be utilized to determine the corrosion rate and estimate the Remaining Life Assessment (RLA) of a storage tank in accordance with the provisions of API 653 – Tank Inspection, Repair, Alteration, and Reconstruction (American Petroleum Institute, 2014). Remaining Life Assessment (RLA) is an important evaluation process used to determine the extent to which a storage tank can continue to operate safely before reaching the minimum allowable thickness specified by applicable standards (Corleto & Hoerner, 2022). The results of the Remaining Life Assessment (RLA) can subsequently serve as a basis for decision-making in future inspection scheduling and maintenance planning activities (Milazzo et al., 2022).

However, technical assessments based solely on thickness measurements and Remaining Life Assessment (RLA) are often insufficient to fully explain the underlying causes of corrosion. Therefore, a Root Cause Analysis (RCA) is required to identify the dominant factors contributing to corrosion, including operating conditions, material characteristics, environmental influences, and drainage system performance (American Petroleum Institute, 2019). One of the most widely used RCA approaches, and the method applied in this study, is the Ishikawa Fishbone Diagram. This method provides a systematic framework for identifying and categorizing potential causes of a problem, enabling a comprehensive analysis of the factors contributing to corrosion (Hekmatpanah, 2011). Furthermore, to establish inspection priorities based on risk levels, a Risk-Based Inspection (RBI) assessment was conducted in accordance with the guidelines provided in API RP 580/581 (American Petroleum Institute, 2016). This method integrates two primary parameters: the Probability of Failure (PoF), which is derived from the Remaining Life Assessment (RLA) results, and the Consequence of Failure (CoF), which reflects the potential impacts of failure on the environment, safety, and economic costs (Javid, 2025). Through the RBI approach, inspection schedules can be planned more effectively by prioritizing equipment with higher risk levels, thereby optimizing maintenance resources while ensuring operational safety and reliability (Tahmid et al., 2022).

Accordingly, this study was conducted to analyze the corrosion rate and Remaining Life Assessment (RLA) of an atmospheric hydrocarbon storage tank in a petroleum processing facility using Ultrasonic Thickness Meter (UTM) measurement data. The study was further complemented by a Root Cause Analysis (RCA) employing the Ishikawa Fishbone Diagram approach and a Risk-Based Inspection (RBI) evaluation to identify the underlying causes of corrosion and provide optimal inspection recommendations for maintaining equipment integrity, safety, and operational reliability.

METHOD

This study employed an applied research approach with a descriptive quantitative design and a case study element focused on a storage tank unit at a petroleum processing facility. The research utilized both field measurement and analytical approaches. The primary objective was to analyze the corrosion rate and estimate the Remaining Life Assessment (RLA) of the storage tank based on plate thickness measurement data obtained from the tank shell using an Ultrasonic Thickness Meter (UTM). Subsequently, a Root Cause Analysis (RCA) was conducted using the Ishikawa Fishbone Diagram approach to identify the main factors contributing to corrosion in the storage tank. In addition, a Risk-Based Inspection (RBI) analysis was performed to determine an appropriate risk-based inspection strategy. In general, the research procedure can be illustrated through the flowchart presented in Figure 1.

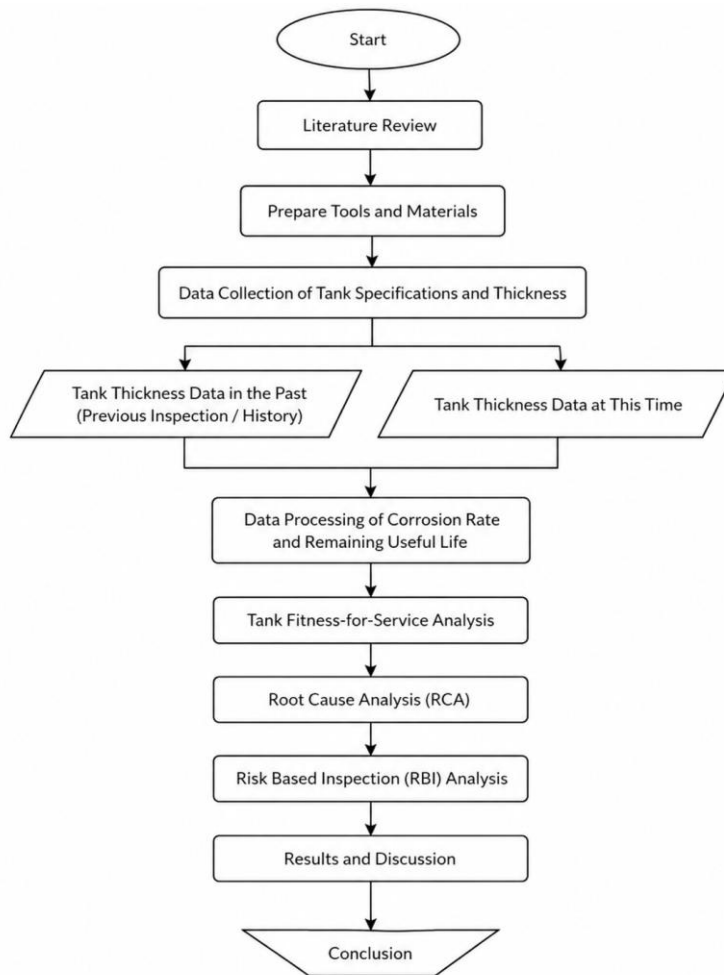


Figure 1. Research Procedure

RESULTS AND DISCUSSION

The thickness measurement data were collected at the Refinery and Utilities Unit. Inspection activities were carried out by measuring the actual wall thickness using an Ultrasonic Thickness Meter (UTM). The UTM is a non-destructive testing (NDT) instrument used to evaluate material dimensions,

detect defects, and assess material condition without causing damage to the component. The thickness measurement results obtained from each tank shell course are presented in Table 1.

Table 1. Tank Shell Course Thickness Measurement Data

TRML		Shell Thickness Measurement Record (mm)										t min (previous)	
Course	Shell	Actual Thickness									t (min)		T (average)
		1	2	3	4	5	6	7	8	9			
Course 1	1 st	4.8	4.7	4.5	4.4	4.4	4.0	5.2	5.7	4.2	3.7	4.7	4
	2 nd	5.8	4.4	5.2	5.4	4.7	5.8	5.3	5.1	4.6			
	3 rd	5.3	5.2	5.1	4.6	5.3	4.4	4.0	4.7	4.3			
	4 th	3.7	4.3	4.0	3.8	4.1	4.1	-	-	-			

*t previous = wall thickness recorded during the 2021 inspection.

Based on the tank thickness measurement data obtained using the Ultrasonic Thickness Meter (UTM), calculations were performed to determine the current tank wall thickness condition, corrosion rate, and Remaining Life Assessment (RLA). Furthermore, Root Cause Analysis (RCA) and Risk-Based Inspection (RBI) evaluations were conducted to identify the causes of corrosion and establish an appropriate inspection strategy. The results of these analyses are presented as follows.

Minimum Thickness Evaluation

The measured wall thickness of the first shell course was found to be 3.7 mm. To determine the minimum required thickness, Equation (1) was applied using a fluid height of 7.447 ft, as shown below.

$$t \min = \frac{2.6 (H-1) D x G}{S x E} \tag{1}$$

Where,

H: Height from tank bottom to maximum liquid level (ft)

D: Tank Diameter (ft)

G: Liquid Specific Gravity

S: Allowable Hydrostatic Stress of the Stored Product (psi), 23.595 psi

E: Joint Efficiency, E = 0.7

$$t \min = \frac{2.6 (7.447-1) 19.6627 x 0.76}{23.595 x 0.7}$$

$$t \min = 0.01516595 \text{ inch}$$

$$t \min = 0.385 \text{ mm} < 3.7 \text{ mm}$$

Based on the minimum thickness calculation for the first shell course, the minimum allowable thickness (t min) was determined to be 0.385 mm. This value represents the lowest permissible thickness required to maintain the structural integrity of the tank in accordance with the design criteria and the requirements of API 653. The Ultrasonic Thickness Meter (UTM) measurements indicated that the minimum actual thickness recorded in the first shell course was 3.7 mm, which is significantly higher than the calculated minimum allowable thickness. Therefore, the actual thickness (t actual) remains above the minimum requirement, indicating that the tank wall continues to satisfy the thickness

acceptance criteria at the time of inspection. This condition suggests that corrosion-related degradation has not yet reached a level that poses an immediate threat to the structural integrity of the tank.

Nevertheless, the difference between the actual thickness and the minimum allowable thickness indicates that the remaining thickness margin will continue to decrease over time. This condition warrants close attention, as wall thinning is expected to persist as long as the tank operates under similar process and environmental conditions. Therefore, a Remaining Life Assessment (RLA) is essential to estimate the duration for which the material can safely remain in service before reaching the minimum allowable thickness limit. By considering both the annual corrosion rate and the current wall thickness, the RLA calculation provides an estimate of when the tank may require reinspection, repair, or other mitigation measures to ensure continued structural integrity and safe operation (Alfon et al., 2013).

Corrosion Rate and Remaining Life Assessment (RLA) Calculation

The corrosion rate and Remaining Life Assessment (RLA) of the storage tank were calculated using Equation (2), as presented below.

$$Corrosion\ Rate = \frac{t_{previous} - t_{actual}}{inspection\ interval\ (time\ difference\ between\ the\ current\ inspection\ and\ the\ previous\ inspection)} \quad (2)$$

$$Corrosion\ Rate = \frac{4\ mm - 3.7\ mm}{2025 - 2021}$$

$$Corrosion\ Rate = 0.075\ mm/year$$

The corrosion rate calculated for the tank shell wall at the first shell course was 0.075 mm/year. To estimate the Remaining Life Assessment (RLA), Equation (3) was subsequently applied, as presented below.

$$RLA = \frac{t_{actual} - t_{min}}{CR} \quad (3)$$

$$RLA = \frac{3.7\ mm - 2.54\ mm}{0.075\ mm/tahun}$$

$$RLA = 15.46\ years$$

Based on the calculation results, it can be observed that the tank has been in service since 1984; nevertheless, its structural condition remains within an acceptable and safe operating range. However, particular attention should be given to areas exhibiting the lowest wall thickness and the shortest remaining service life. Therefore, periodic inspections and appropriate maintenance actions are necessary to prevent potential tank failures. This analysis demonstrates that thickness evaluation and remaining life estimation play a critical role not only in ensuring compliance with safety requirements but also in enhancing operational efficiency and supporting more effective maintenance planning within the oil and gas industry (Animah & Shafiee, 2018).

Root Cause Analysis (RCA)

Root Cause Analysis (RCA) was conducted to identify the underlying factors contributing to wall thickness reduction in the storage tank. The RCA findings serve as the basis for developing corrective actions and preventive measures aimed at minimizing recurring degradation and enabling a more effective and targeted inspection management strategy.

RCA can be performed using various analytical techniques, one of the most widely applied being the Ishikawa Fishbone Diagram. This method is used to systematically map potential causes into specific categories and trace the root causes of the identified problem. The analysis in this study was based on data obtained from UTM thickness measurements, historical inspection records, maintenance reports, operational logs, and field observations. Figure 2 presents the Ishikawa Fishbone Diagram illustrating the factors contributing to corrosion in the storage tank.

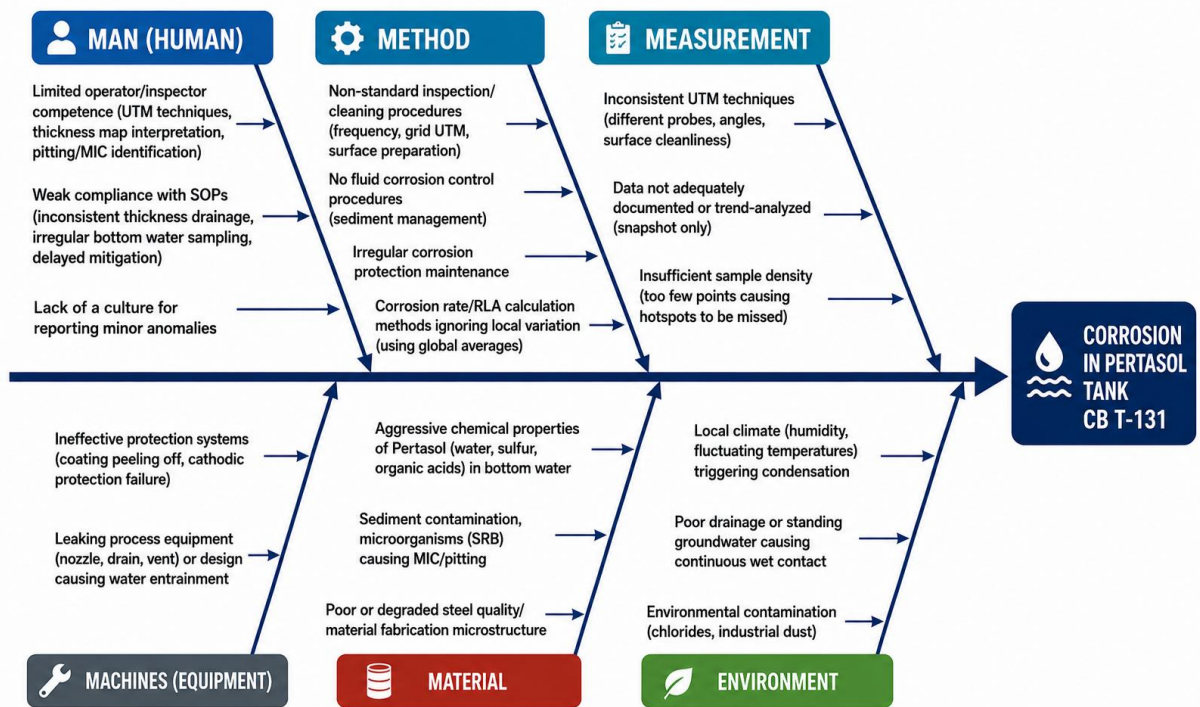


Figure 2. Fishbone Diagram of Factors Contributing to Storage Tank Corrosion

Corrosion in the storage tank was identified as the primary cause of structural integrity degradation in the tank shell and has the potential to result in leakage, safety hazards, and environmental consequences. The corrosion process is multifactorial in nature, arising from the interaction of fluid characteristics (such as water content, sulfur compounds, and aromatic constituents), operating conditions, material quality and protection systems, as well as deficiencies in procedures and measurement practices. The Ishikawa Fishbone Diagram was employed to systematically map the contributing factors across the six domains of the 5M+1E framework, thereby providing a structured basis for data-driven recommendations aimed at corrosion mitigation and prevention.

1. Man

a. Identification of Potential Root Causes

- Limited competency of operators and inspectors in UTM inspection techniques, including the interpretation of wall thickness mapping and the identification of pitting corrosion or microbiologically influenced corrosion (MIC) indications.
- Weak compliance with standard operating procedures (SOPs), such as inconsistent drainage management, irregular bottom-water sampling, and delayed implementation of mitigation measures.
- Insufficient reporting culture for minor defects and abnormalities, resulting in early signs of corrosion not being properly documented, communicated, or escalated for corrective action.

b. Field Evidence and Indicators

- UTM inspection results indicate unexpected variations in wall thickness measurements across different inspection points, suggesting potential inconsistencies in corrosion distribution or measurement practices.
- Inspection records are incomplete, and minor findings or early indications of degradation have not been adequately followed up, potentially allowing corrosion mechanisms to progress without timely corrective action.

c. Corrective and Preventive Action Recommendations

- Conduct intensive training programs for operators and inspectors on UTM inspection practices, including probe calibration, measurement techniques, data interpretation, and preventive corrosion monitoring.
- Revise and strengthen inspection SOPs by implementing mandatory checklists for bottom-water sampling, drainage monitoring, and routine tank cleaning activities to ensure consistent execution of corrosion control measures.
- Establish a continuous competency development program and implement an integrated near-miss and degradation reporting system to improve early detection, knowledge retention, and proactive corrosion management.

2. Machines

a. Identification of Potential Root Causes

- Ineffective corrosion protection systems, including coating degradation, coating disbondment, or malfunctioning cathodic protection systems that reduce the tank's resistance to corrosive environments.
- Deficiencies in processing equipment, such as leaking nozzles, drains, or vents, as well as design configurations that promote water accumulation or the ingress and retention of contaminants, thereby accelerating corrosion processes.

b. Field Evidence and Indicators

- Localized coating deterioration, peeling, or disbondment observed during visual inspections, indicating reduced effectiveness of the protective barrier against corrosion.
- Cathodic protection maintenance records showing voltage, current output, or polarization levels below the specified operational requirements, suggesting inadequate corrosion protection performance.
- Inconsistent UTM measurement results between different inspectors or inspection periods, potentially indicating variations in measurement practices, equipment calibration, or data interpretation.

c. Corrective and Preventive Action Recommendations

- Conduct comprehensive visual inspections, repair damaged coating areas, and verify the performance and functionality of the cathodic protection system to ensure adequate corrosion control.
- Implement regular UTM calibration procedures, utilize transducers appropriate for the inspected material and thickness range, and install permanent monitoring sensors to track wall-thickness loss and corrosion progression.
- Retrofit nozzles, drains, and related components to minimize water accumulation and contaminant trapping, while establishing a scheduled maintenance program for cathodic protection systems and protective coatings to ensure long-term asset integrity.

3. Method

a. Identification of Potential Root Causes

- Inspection and tank cleaning procedures are not fully aligned with applicable standards, particularly with respect to inspection frequency, UTM measurement grid coverage, and surface preparation requirements.
- The absence of, or non-compliance with, procedures for monitoring and controlling fluid quality, including the management of water accumulation, sludge, and sediment deposits that may accelerate corrosion.
- Corrosion protection systems are not maintained on a regular basis, resulting in reduced effectiveness of coatings, cathodic protection systems, or other mitigation measures.
- Corrosion rate and Remaining Life Assessment (RLA) calculations rely on global average values without adequately considering localized corrosion variations, potentially masking severe pitting or localized wall-thinning conditions.

b. Field Evidence and Indicators

- UTM inspections do not follow the measurement grid recommended by API 653, increasing the likelihood that critical corrosion areas or localized thinning regions may be overlooked.

- RLA documentation does not include localized pitting assessments or analyses of seasonal variations in corrosion behavior, potentially resulting in an incomplete representation of the actual degradation condition of the tank.
- c. Corrective and Preventive Action Recommendations
 - Re-establish standard measurement grid practices in accordance with applicable inspection requirements, implement proper surface cleaning procedures prior to UTM measurements, and perform repeat measurements in identified critical areas to improve data reliability.
 - Enhance the RLA methodology by incorporating thickness distribution analyses, such as histogram-based evaluations and pitting factor assessments, rather than relying solely on average thickness values, thereby improving the detection of localized corrosion damage.
 - Implement an RBI-driven inspection program in which inspection intervals and scopes are determined based on the Probability of Failure (PoF) and Consequence of Failure (CoF), rather than fixed time-based schedules, to optimize inspection effectiveness and resource allocation.
- 4. Material
 - a. Identification of Potential Root Causes
 - The chemical composition of Pertasol, particularly its water, sulfur, aromatic, and organic acid contents, promotes aggressive corrosion conditions, especially at the tank water-bottom interface.
 - Contaminants such as salinity, sediments, and sulfate-reducing bacteria (SRB) facilitate localized corrosion processes, including pitting corrosion and microbiologically influenced corrosion (MIC).
 - Inadequate material selection, fabrication deficiencies, or degradation of the tank steel microstructure may further accelerate corrosion damage and reduce structural integrity.
 - b. Field Evidence and Indicators
 - The detection of localized pitting through UTM inspections and metal loss patterns inconsistent with the expected design behavior suggests the occurrence of non-uniform corrosion processes and potential localized degradation mechanisms.
 - c. Corrective and Preventive Action Recommendations
 - Corrective actions should focus on water-bottom removal, sediment cleaning, chemical and microbiological characterization, and the application of appropriate demulsifiers or biocides based on the identified contamination mechanisms.

- Fluid quality management should be enhanced through the implementation of inline dewatering technologies, improved separation efficiency, and stricter feedstock quality assurance practices.
- A comprehensive assessment of material compatibility should be undertaken, including potential material upgrades, the application of internal protective coatings or linings, and proactive monitoring and control of water accumulation to mitigate future corrosion risks.

5. Measurement

a. Identification of Potential Root Causes

- Variability in UTM inspection techniques, including differences in probe selection, measurement orientation, and surface condition, can introduce uncertainty into wall-thickness assessments.
- Limited documentation and the absence of longitudinal trend analysis may hinder the identification of corrosion progression and degradation patterns.
- An insufficient UTM sampling density may result in localized corrosion damage, including pitting and hotspot regions, remaining undetected, thereby underestimating the actual extent of material degradation.

b. Field Evidence and Indicators

- Variability in ultrasonic thickness measurement (UTM) results across successive inspections, coupled with incomplete baseline thickness records and the absence of updated thickness contour maps, limits the ability to accurately evaluate corrosion progression and structural integrity.

c. Corrective and Preventive Action Recommendations

- Inspection reliability should be enhanced through the standardization of UTM procedures, including calibration verification, proper couplant usage, adequate surface preparation, and consistent probe positioning. Additional measurements using a high-density inspection grid are recommended for critical regions.
- A comprehensive inspection data management framework should be established, integrating thickness mapping, corrosion rate trending, and control-chart-based monitoring to support data-driven maintenance decisions.
- Advanced nondestructive testing (NDT) techniques, including phased-array UT, guided wave inspection, and permanently installed ultrasonic monitoring systems, should be deployed to improve the early detection and continuous monitoring of wall loss and pitting corrosion.

6. Environment

a. Identification of Potential Root Causes

- The prevailing local climate, characterized by elevated humidity levels and temperature fluctuations, can enhance moisture condensation and water accumulation within the tank system.
 - Inadequate drainage infrastructure, unfavorable environmental design, groundwater leakage, or persistent water ponding around the tank foundation may lead to prolonged wet conditions that accelerate corrosion processes.
 - Exposure to environmental contaminants, including chloride-bearing deposits and airborne industrial particulates, may contribute to the development of aggressive corrosive environments and increase susceptibility to localized corrosion.
- b. Field Evidence and Indicators
- The occurrence of accelerated external corrosion in soil-contact and splash-zone areas indicates the significant influence of environmental exposure and moisture retention on the degradation process.
- c. Corrective and Preventive Action Recommendations
- Effective water-drainage and tank-cleaning practices should be maintained, while headspace dehumidification and thermal insulation systems may be considered to mitigate condensation-related corrosion.
 - Improvements to site grading and drainage infrastructure should be undertaken, accompanied by the application of external coating systems designed for corrosive service environments.
 - Design modifications including tank elevation on an optimized ringwall foundation and enhancement of bund-area drainage systems should be evaluated. Furthermore, continuous environmental monitoring of relative humidity and atmospheric corrosivity is recommended to support proactive corrosion management.

The Ishikawa Fishbone-based RCA identified corrosion of the tank shell as a multifactorial phenomenon arising from the interaction of material, operational, environmental, and human-related factors. The aggressive chemical characteristics of Pertasol, including its water content, sulfur-bearing compounds, aromatic constituents, and microbiological contaminants, created favorable conditions for corrosion initiation and propagation. The severity of degradation was amplified by reduced corrosion protection effectiveness, evidenced by deterioration of the internal coating system and inadequate cathodic protection performance. Furthermore, human-related factors, such as insufficient operator proficiency in ultrasonic thickness measurement (UTM) and inconsistent adherence to inspection procedures, contributed to uncertainty in corrosion monitoring and the timely detection of degradation.

Inspection and measurement related deficiencies, including deviations from standardized inspection procedures, inadequate measurement point density, and insufficient documentation and corrosion trend analysis, limited the effectiveness of corrosion monitoring and assessment. Moreover,

environmental factors such as elevated humidity, cyclic temperature variations, and poor drainage conditions contributed to the acceleration of both internal and external corrosion mechanisms. Collectively, these findings demonstrate that shell corrosion is a complex multifactorial degradation process that cannot be attributed to a single cause. Consequently, effective mitigation requires a holistic approach encompassing improvements in corrosion control systems, inspection practices, operational management, and environmental control measures.

Overall, effective corrosion control in storage tanks requires improvements in personnel competency, refinement of inspection and maintenance practices, enhancement of corrosion protection systems, optimization of environmental and site design, and the implementation of a more structured measurement data management framework (Sun & Li, 2010). The implementation of this comprehensive strategy is critical for preserving tank integrity, ensuring safe and reliable operation, and minimizing corrosion-related operational risks over the long term.

Risk-Based Inspection (RBI)

Risk-Based Inspection (RBI) is a systematic methodology used to optimize inspection planning by prioritizing equipment according to its risk of failure. In the RBI framework, risk is quantified as the combination of the Probability of Failure (PoF) and the Consequence of Failure (CoF). The PoF reflects the likelihood that a failure event will occur during the designated assessment interval. For corrosion-driven assets, such as Pertasol storage tanks, the PoF may be evaluated based on the Remaining Life Assessment (RLA), which provides an indication of the asset's remaining serviceability. The resulting PoF category is determined using the classification criteria summarized in Table 2.

Table 2. Probability of Failure (PoF) Classification

Pof Category	General Criteria	Description
Very Low (1)	RLA > 20 years	Wall thickness is still far above the minimum requirement
Low (2)	RLA 10 - 20 years	Still in a safe condition
Medium (3)	RLA 5 - 10 years	Requires monitoring
High (4)	RLA 2 - 5 years	Increasing potential for failure
Very High (5)	RLA < 2 years	Risk of failure is imminent

Based on the PoF classification matrix and the estimated remaining life of 15.46 years, the Pertasol storage tank is assigned to the low-risk PoF category (score = 2). This result suggests that the likelihood of failure due to corrosion-related degradation is relatively low, and the tank is currently fit for continued operation, provided that routine inspection and maintenance activities are maintained.

The Consequence of Failure (CoF) refers to the severity of the impacts that may occur if the storage tank experiences an actual failure. The CoF assessment is conducted by considering several key parameters, including the type of fluid stored, the quantity of fluid, the tank location, and the availability of protective systems. The CoF approach adopted in this study is based on a scoring and categorization model, in which each parameter is assigned a specific weighting factor and subsequently combined to

determine the overall consequence category. In general, the assessment methodology follows the principles outlined in API 581, as summarized in Table 3.

Table 3. Consequence of Failure (CoF) Assessment

No	Parameter	Criteria	Description	Score
1	Fluid Type	Light hydrocarbon (Pertasol/naphtha), flammable	fluid volatile, The fluid has high volatility, is highly flammable, and may cause fire/explosion in the event of a leak. The potential environmental impact is also significant.	4 - High
2	Fluid Volume or Quantity	< 300 m ³	Spill impact is smaller and easier to control.	2 - Low
3	Physical Location	Area with low-to-medium traffic activity, with workers/process facilities/storage present	Greater potential impact on personnel/operations if a leak occurs.	3 - Medium
4	Protection System	Complete protection: good internal coating, optimal bund area, leak detection, adequate fire-fighting system	Damage can be minimized, thereby significantly reducing consequences.	2 - Low

Based on the CoF assessment framework, which incorporates fluid type, inventory volume, physical location, and protection system effectiveness as the principal evaluation parameters, the storage tank was assigned to the medium consequence category. The calculated CoF value is given in Equation (4).

$$CoF\ Average = \frac{4+2+3+2}{4} = 2.75 \approx 3.00\ (low - medium) \tag{4}$$

The CoF assessment yielded an average score of approximately 3.00 on a five-point scale, placing the storage tank within the medium consequence category. Although the fluid inventory is relatively limited and protective measures have been implemented, the potential impacts associated with shell failure cannot be considered negligible. Such a failure could result in operational interruptions, localized fire incidents, and adverse environmental consequences. These findings underscore the importance of adopting comprehensive mitigation measures, including enhancing the performance of protection systems, improving the monitoring of tank structural integrity, and optimizing risk-based inspection programs to reduce the likelihood and severity of future failure events.

Following the determination of the CoF category for the Pertasol storage tank, the overall risk level was evaluated using Equation (5). The calculation methodology is presented below.

$$Risk\ Level = PoF \times CoF \tag{5}$$

$$Risk\ Level = 2 \times 3$$

$$Risk\ Level = 6$$

The calculated Risk Level of 6 places the Pertasol storage tank in the medium-risk region of the RBI matrix. Given the low PoF rating and medium CoF rating, the tank is positioned within the yellow risk zone. This risk ranking serves as a key input for risk-based inspection planning, supporting the optimization of inspection intervals, inspection methodologies, and mitigation actions aimed at reducing the likelihood and consequences of future failure events while maintaining asset integrity.

A medium risk classification reflects a condition in which both the Consequence of Failure (CoF) and the Probability of Failure (PoF) remain within acceptable limits, although continued degradation could potentially increase the overall risk level. Consequently, risk mitigation efforts should emphasize systematic monitoring, appropriate adjustment of inspection intervals, and the application of advanced inspection methods capable of providing more reliable condition assessments. The fundamental mitigation principle for this category is the early detection of corrosion and other degradation mechanisms, thereby facilitating proactive maintenance actions and preventing risk escalation to high- or extreme-risk conditions.

Table 4. Risk Matrix

Likelihood/Probability	Consequence 1 (Minor)	Consequence 2 (Moderate)	Consequence 3 (Major)	Consequence 4 (Severe)	Consequence 5 (Catastrophic)
1 (Rare)	Low	Low	Low	Medium	Medium
2 (Unlikely)	Low	Low	Medium	Medium	High
3 (Possible)	Low	Medium	Medium	High	High
4 (Likely)	Medium	Medium	High	High	Extreme
5 (Almost Certain)	Medium	High	High	Extreme	Extreme

Note:

Probability of Failure (PoF): Likelihood/Probability (declining)

Consequence of Failure (CoF): Consequence (stable)

For equipment assigned to the medium-risk category, mitigation efforts should focus on enhancing the effectiveness of risk-based inspection programs. This includes increasing inspection frequency in regions where wall thinning, localized pitting, or abnormal corrosion-rate trends have been identified. Inspection intervals may be shortened from conventional schedules (e.g., five-year intervals) to two- or three-year intervals, or determined in accordance with API 653 and API 580/581 guidelines using Remaining Life (RL) and Remaining Life Ratio (RLR) evaluations. In addition, advanced non-destructive examination (NDE) methods, including UTM grid mapping, Phased Array Ultrasonic Testing (PAUT), and Magnetic Flux Leakage (MFL), should be employed to improve defect detection capability, enhance thickness-loss characterization, and minimize uncertainty in integrity assessment results.

Beyond inspection optimization, complementary technical mitigation measures should be implemented to address the underlying causes of degradation. These measures include enhancing corrosion protection systems through coating rehabilitation, internal lining upgrades, and improved cathodic protection performance, as well as maintaining fluid quality and controlling operational environmental factors that contribute to corrosion. While inspection-based mitigation remains the central element of the risk management strategy, these engineering controls are designed to lower the Probability of Failure (PoF) and support the transition of the asset to a lower risk category during future RBI evaluations.

CONCLUSION

The results of the corrosion assessment, ultrasonic thickness measurements, Remaining Life Assessment (RLA), and Risk-Based Inspection (RBI) evaluation indicate that the Pertasol storage tank shell currently exhibits a low-to-medium risk profile. The tank maintains sufficient structural integrity for ongoing service; however, localized corrosion phenomena were identified in regions prone to moisture accumulation, contaminant presence, and reduced corrosion protection effectiveness. Although the current risk classification remains within acceptable limits, the observed degradation mechanisms highlight the possibility of future risk escalation. Therefore, continued monitoring and the implementation of effective inspection and mitigation strategies are essential to ensure long-term asset integrity and operational reliability.

In summary, the low-to-medium risk profile confirms that the tank remains fit for continued service; however, proactive integrity management is required to address localized degradation mechanisms. The integration of risk-based inspection practices, effective corrosion mitigation measures, and robust operational controls is essential for sustaining asset reliability, preventing risk escalation, and ensuring the long-term safe operation of the storage tank. Furthermore, the results provide a basis for optimizing inspection intervals and maintenance planning by prioritizing high-risk areas and aligning intervention strategies with remaining life assessments.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the management and technical staff of the petroleum processing facility for their support, cooperation, and provision of inspection and operational data essential to this study. The authors also appreciate the valuable contributions of colleagues and reviewers whose insights helped enhance the quality of the research. Finally, the authors acknowledge the support of their respective institutions in facilitating the completion and dissemination of this work on corrosion rate analysis and remaining life assessment of atmospheric hydrocarbon storage tanks.

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