

Innovation in Inspection Planning Using the Corrosion Assessment Information System (CAIS) Analytical Tool to Prevent Stationary Equipment Failure in Crude Distillation Unit (CDU)

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ABSTRACT - Equipment failure due to corrosion remains one of the significant challenges in maintaining oil refinery asset integrity within the oil and gas processing industry. This study aims to develop a corrosion assessment information system (CAIS), designed to evaluate and visualize the severity of equipment corrosion with a color-coded process flow diagram (PFD) interface. The system facilitates corrosion simulation based on standard damage mechanisms resulting from impurities in crude oil. CAIS significantly enhances the efficiency, accuracy, and cross-functional collaboration in corrosion monitoring activities. The development methodology of CAIS comprises four main stages. First is the compilation, evaluation, and analysis of design and operational data obtained from laboratory testing. The second stage involved process simulation and validation using actual data for each equipment. In the third stage, simulated impurity data are compiled and organized into Excel-based tables for each unit in the crude distillation unit (CDU). Finally, the data are used to identify potential corrosion mechanisms in accordance with American petroleum institute 581 and 571 standards. External validation and system integration within the organizational workflow demonstrate that CAIS is a strategic digital solution supporting risk-based inspection practices and predictive maintenance in PT Kilang Pertamina Internasional Refinery Unit VI Balongan, Indonesia.

Keywords: oil refinery asset integrity, corrosion assessment information system (CAIS), corrosion monitoring software, stationary equipment failure, crude distillation unit (CDU).

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INTRODUCTION

Crude distillation unit (CDU) plays a pivotal role in the oil refining process, acting as the initial stage in separating crude oil into its constituent components, and the variability of crude oil sources processed by PT Kilang Pertamina Internasional Refinery Unit VI Balongan introduces a diverse range of complex contaminants, including salts, water, and organic compounds, each of which has the potential to initiate corrosive processes (Mohammed et al., 2024; Lucia 2011). Several documented cases of corrosion-induced failures include stress corrosion cracking in vessels due to elevated sulfur content, leakage in heat exchanger tubes associated with high chloride concentrations, and catastrophic tank failures (Wang et al., 2020; Yang et al., 2020). The leakage data from the CDU unit in stationary equipment caused by corrosion are presented in Figure 1. Implementing effective monitoring technologies and risk management strategies is critical to mitigating the impact of corrosion and enhancing operational safety performance within the oil and gas industry (Ondinde et al., 2023). Conventional approaches such as Risk-based inspection (RBI) are still widely used;

however, these methods exhibit significant limitations in terms of flexibility and data updating speed, as inspections typically require shutdown conditions to be performed (Arena et al., 2022; Hameed 2016). In parallel, the ongoing digital transformation and the increasing demand for real-time monitoring necessitate the development of more responsive and adaptive systems (Antonyuk et al., 2019; Zavala 2017). Real-time corrosion monitoring systems that can dynamically adapt to changing operational conditions have the potential to significantly improve the effectiveness of corrosion risk management in the oil and gas sector (Zurkanain & Subramaniam 2023; Abdulwahab et al., 2022; Wright et al., 2019). Nevertheless, real-time corrosion monitoring technologies are not without limitations. They often struggle to differentiate between corrosion and erosion phenomena and typically require a minimum of 30 days to yield accurate results (Liao et al., 2023; Balasubramanian et al., 2023). Integrating real-time corrosion monitoring with complementary methods such as corrosion inhibitors has been proposed (Popova et al., 2024; Qin et al., 2023; Ramachandran 2017).

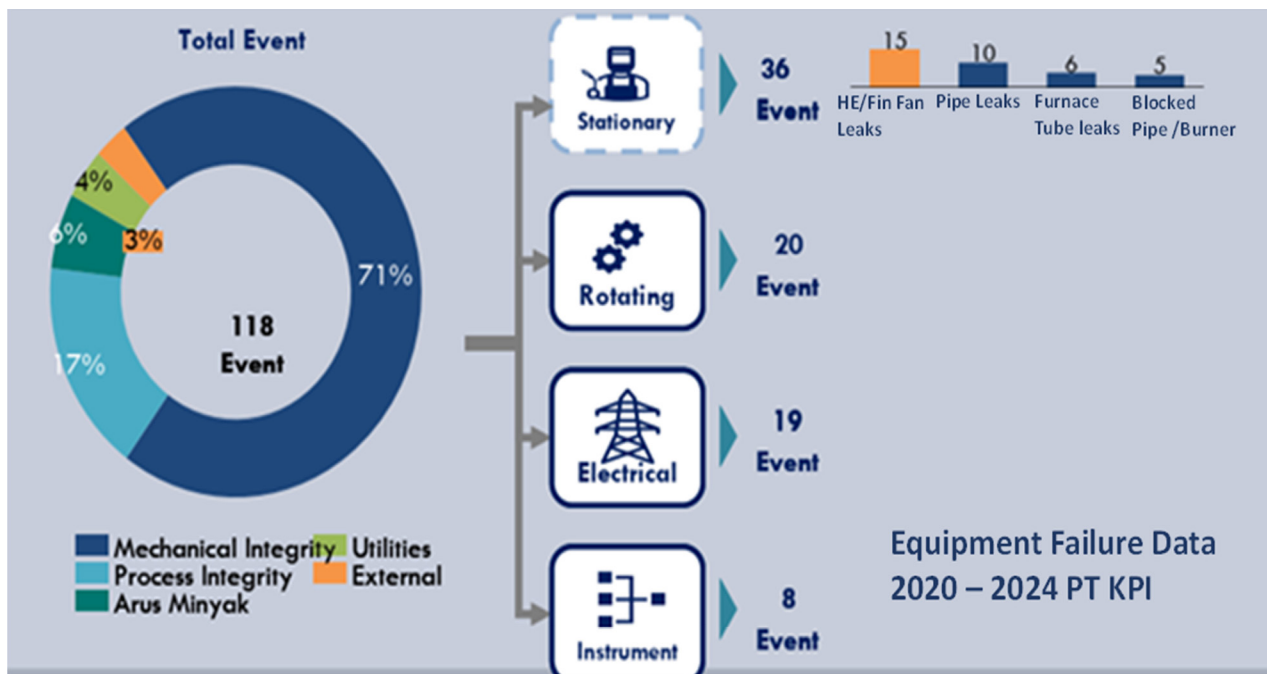


Figure 1. The failure data from the CDU unit in stationary equipment (Pertamina 2024)

However, reliance on corrosion inhibitors also presents notable drawbacks. These include dependence on the volume of inhibitor used, limited capability to determine the specific corrosion mechanism, delayed assessment of effectiveness, and high implementation costs (Khan et al., 2022; Hatamov 2022). Although both real-time monitoring and inhibitor technologies can be beneficial, a comprehensive evaluation of the overall risk management system remains essential to effectively minimize the impact of corrosion at PT Kilang Pertamina Internasional Refinery Unit VI. To address these challenges, there is a pressing need to develop a more effective solution for monitoring and managing corrosion. Therefore, the primary objective of this study is to develop the CAIS. This analytical tool provides comprehensive corrosion simulation and enables intuitive data visualization. It delivers accurate, real-time data on corrosion conditions, thereby supporting informed decision-making in risk management. Moreover, CAIS is intended to serve as a valuable decision-support tool for engineers and managers in planning more effective corrosion mitigation strategies. The system also seeks to strengthen collaboration between technical and management teams in optimizing maintenance strategies, ultimately extending equipment lifespan and minimizing the risk of failure. The methodology employed in the CAIS solution involves the rigorous analysis of impurity data, operational parameters, material characteristics, and process variables in alignment with the corrosion rate and corrosion mechanism criteria defined by the American petroleum institute 581 and American petroleum institute 571 standards. Subsequently, various types of corrosion are represented through color-coded corrosion emulation models displayed on the PFD, enabling a more intuitive and actionable interpretation of corrosion risks.

METHODOLOGY

The development of the CAIS was conducted using a software engineering approach tailored to refinery operational needs. Careful consideration of corrosion-related technical parameters and the integration of field data were key stages of the methodology.

System design

The CAIS architecture was developed as a platform to ensure high accessibility and interoperability. The system incorporates a visual classification scheme based on a PFD, in which color coding represents varying levels of corrosion risk.

Data collection and integration

Structured input of crude oil impurity data and equipment design specifications was carried out. The system also supports integration with historical inspection records, failure logs, and other relevant technical documentation. Sampling data from existing sampling points was required for validation with process simulation. The sampling point is presented in Table 1.

Process and corrosion modeling

Process simulation was conducted to establish mass and heat balances in the CDU under steady-state conditions (Fuad 2013). Subsequently, corrosion rate calculations were performed per American petroleum institute 581 standards based on the process simulation results. The extracted data depended on the type of corrosion being calculated and monitored. Nine major damage mechanisms are commonly found in CDUs, including High-Temperature Sulfidic/Naphthenic Acid Corrosion and Hydrogen Sulfide Corrosion.

Table 1. The sampling point in CDU

No.	Sampling Point	Fluid Types
1	Crude Charge Battery Limit to OM	Hydrocarbon
2	Desalted Crude (Suction Pump 11-P-102)	Hydrocarbon
3	Naphtha Column 11-C-104 (11-LV-030)	Hydrocarbon
4	Naphtha Column 11-C-105 (11-FV-037)	Hydrocarbon
5	Kerosene (11-E-127)	Hydrocarbon
6	Light Gasoil (11-FV-032)	Hydrocarbon
7	Combine Gasoil (Dekat 11-P-103C)	Hydrocarbon
8	Heavy Gasoil (11-FV-031)	Hydrocarbon
9	Residue (11-FV-033)	Hydrocarbon
10	Desalter Effluent Water (11-E-128 A/B)	Water
11	Sour Water Overhead (11-V-102)	Water
12	Sour Water Overhead 11-V-116 (Discharge Pump 126)	Water
13	Sour Water Overhead 11-V-104	Water

Testing and validation

A prototype was tested at Refinery Unit VI, including independent technical validation conducted by PT LAMerican petroleum institute ITB to ensure that the simulation results accurately reflected field conditions. The validation process involved comparing the simulated results and field data from sampling points, with a maximum error margin of 10%. The required data from the simulation were input into the equipment and piping group table for real-time and straightforward monitoring. The equipment and piping group was created based on corrosion circuits developed from the revamped process flow diagram of the CDU. For example, the fluid flowing through the heat exchanger experienced changes in pressure and temperature but no change in composition. Furthermore, it was possible to determine that fluids with the same composition flowing through a heat exchanger would have similar corrosion potential, which is further adjusted based on operating temperature and pressure.

Implementation and training

The system was continuously implemented at PT Kilang Pertamina Internasional Refinery Unit VI, with technical training sessions and cross-functional socialization programs to ensure user competency and operational effectiveness. This approach was designed to ensure that CAIS is technically feasible, operationally relevant, and readily adoptable by multiple stakeholders within the oil refining industry. Furthermore, the CAIS development process follows a four-phase workflow, as illustrated in Figure 2.

Phase 1: Data compilation and analysis

Compilation, evaluation, and analysis of equipment design data, operational data, process data, and impurity data obtained from laboratory testing.

Phase 2: Process simulation and validation

Simulation and validation were conducted using the impurity data specific to each piece of equipment. This step enabled the identification of impurity presence in other equipment that had not been previously characterized.

Phase 3: Data structuring and visualization

Simulated impurity data were compiled and formatted into Excel tables for each item of equipment within the CDU unit.

Phase 4: Corrosion Mechanism Identification

Impurity data were then used to identify potential corrosion mechanisms based on impurity type, operating conditions, and construction materials. The corrosion mapping study began by collecting feedstock data and operating conditions from the CDU. These data were obtained from the “Detailed Heat and Material Balances Unit CDU” documentation. The simulation was based on the following data inputs and modeling assumptions: 1). Crude Assay: Crude characterization was used to generate the composition and properties of crude oil; 2). Operating Pressure and Temperature: Equipment pressure and temperature conditions were derived from the PFD, while product flow rates for LGO, HGO, residue, naphtha, and kerosene were based on actual plant data from the corresponding feedstock blending date; 3). Impurity Data: The simulation incorporated actual impurity values for sulfur, total acid number (TAN), hydrogen sulfide (H₂S), chloride ions (Cl⁻), and ammonia (NH₃); 4). Thermodynamic Model: The Peng-Robinson TWU equation of state was used as the fluid package for the simulation; 5). sulfur modeling: Sulfur content was modeled using four representative compounds C₃H₁₂S, C₇H₁₆S, C₁₄H₃₀S, and C₁₈H₃₄S to simulate both light and heavy sulfur fractions; 6). TAN modeling: TAN was represented using five carboxylic acid compounds—C₃H₆O₂, C₄H₈O₂, C₁₀H₁₂O₂, C₁₅H₃₀O₂, and C₂₀H₄₀O₂—as proxies for light and heavy fractions; 7). Chloride Modeling: Chloride components were modeled using HCl and NaCl.

These data inputs were used to develop a process model using a simulation software platform. The simulation outputs were subsequently validated against actual field data to ensure consistency and reliability. The identification of corrosion mechanisms and corrosion rate calculations were based on the guidelines provided in American petroleum institute Recommended Practice 581 (American petroleum institute RP 581) and American petroleum institute 571. The primary corrosion mechanisms considered for the CDU unit include: 1). High-temperature sulfidic/naphthenic acid corrosion (HTSNA); 2). Hydrochloric acid (HCl) corrosion; 3). Hydrogen sulfide/hydrogen (H₂S/H₂) Corrosion; 4). Sour water gas corrosion; 5). Alkaline sour water corrosion; 6). Chloride stress corrosion cracking (Cl-SCC); 7). Sulfide stress cracking; 8). Caustic stress corrosion cracking; 9). High-temperature hydrogen attack (HTHA).

The severity of corrosion was assessed based on the maximum calculated corrosion rate among the nine mechanisms. Corrosion severity was categorized using the following corrosion rate thresholds (expressed in millimeters per year, or mmpy): 1). Low: < 0.05 mmpy; 2). Moderate: $0.05 - 0.51$ mmpy; 3). High: $0.51 - 1.27$ mmpy; 4). Severe: > 1.27 mmpy.

This classification provided a systematic framework for evaluating corrosion risk levels across the CDU equipment, supporting more informed decision-making in inspection planning and asset integrity management.

CAIS operates as a software application capable of visually assessing corrosion conditions through a color-coded PFD, enabling identification of areas with the highest corrosion risk. The corrosion severity visualization within CAIS is categorized into four color-coded levels: 1). Green: Low risk; 2). Blue: Moderate risk; 3). Yellow: High risk; 4). Red: Very high risk.

Green indicates an extremely low corrosion rate requiring no immediate action, while red denotes a high severity level with significant threats to equipment integrity, necessitating immediate attention. This color-coding scheme supports

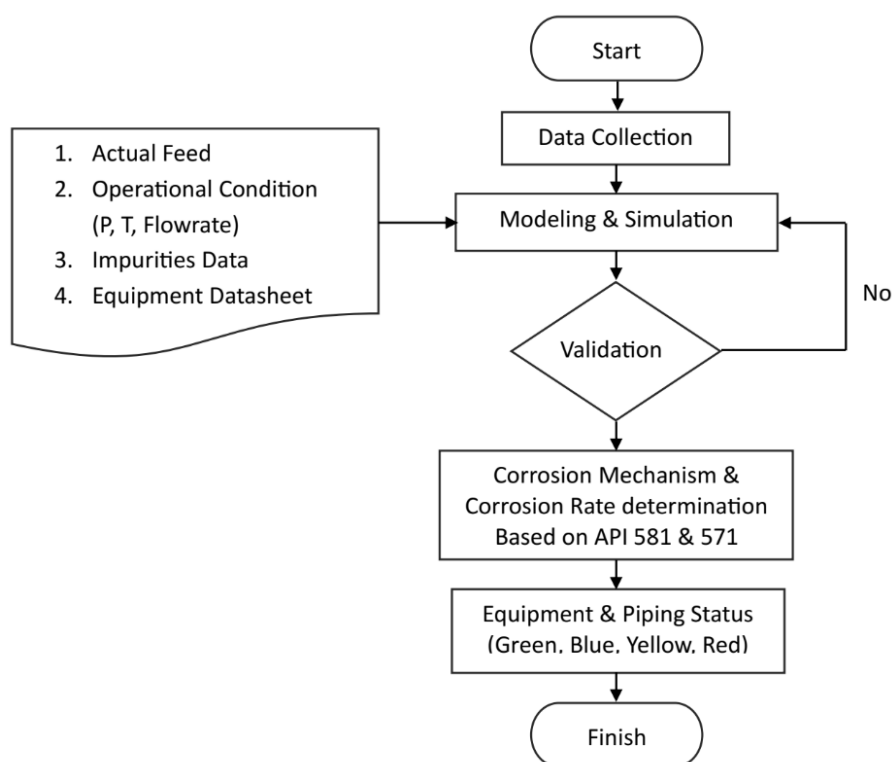


Figure 2. Flowchart of CAIS development process

RESULT & DISCUSSION

Development of an analytical tool for evaluating corrosion severity in refinery equipment

Before evaluating the corrosion severity, a process simulation was conducted to validate the flow rate and composition of the product in the CDU. Tables 2 and 3 exhibited that the margin of error of flow rate and composition of impurities was less than 10%. This simulation can be claimed to be appropriate for the actual condition. This study has developed an analytical tool named the CAIS, designed to evaluate the severity of damage in refinery equipment caused by corrosion phenomena.

decision-making processes in prioritizing inspection and maintenance activities. The corrosion rate assessment within the system is based on the American petroleum institute 581 Base Resource Document guidelines, considering damage mechanisms induced by impurities in processed crude oil. Additional factors, such as material type, operating conditions, fabrication processes, and heat treatment histories, are also considered. By integrating visual corrosion severity assessments with technical modeling based on industry standards, CAIS is a strategic tool to enhance asset integrity management and corrosion monitoring in refinery operations.

Table 2. Validation of flow rate in CDU

Crude type	remarks	Flow rate (Ton/h)					Off-Gas (Nm ³ /h)
		LGO	HGO	Residue	Naphta	Kerosene	
01/12/2020 (Mix Crude 1)	Actual	85,95	19,95	396,98	30,98	35,70	123,62
	Simulation	84,32	19,34	413,70	29,50	33,76	123,70
	% error	2%	3%	4%	-5%	5%	0%
21/12/2020 (Mix Crude 2)	Actual	89,77	38,42	367,60	28,47	49,73	102,87
	Simulation	88,87	37,97	391,17	28,10	49,44	106,80
	% error	1%	1%	6%	1%	1%	4%
22/12/2020 (Mix Crude 3)	Actual	102,74	33,96	387,65	28,14	54,04	124,11
	Simulation	101,40	33,30	415,98	27,00	54,90	123,80
	% error	1%	2%	7%	4%	2%	0%

Table 3. Validation of impurities in CDU

Crude type	Remarks	LGO			HGO			Residue		
		Sulfur	TAN	Cl ⁻	Sulfur	TAN	Cl ⁻	Sulfur	TAN	Cl ⁻
01/12/2020 (Mix Crude 1)	Actual	878,00	0,45	2,70	1955,00	1,10	2,90	3150,00	1,00	6,70
	Simulation	874,97	0,48	2,87	2055,26	1,04	3,18	3064,72	0,90	6,62
	% error	0%	7%	6%	5%	5%	10%	3%	10%	1%
21/12/2020 (Mix Crude 2)	Actual	1664,00	0,91	4,10	2483,00	1,65	4,60	2781,00	1,24	5,70
	Simulation	1740,46	0,82	3,74	2288,18	1,55	4,79	2550,72	1,14	5,19
	% error	5%	10%	9%	8%	6%	4%	8%	8%	9%
22/12/2020 (Mix Crude 3)	Actual	1664,00	0,91	4,10	2483,00	1,65	4,60	2781,00	1,24	5,70
	Simulation	1785,57	0,96	4,46	2673,00	1,80	5,02	2508,20	1,16	6,16
	% error	7%	6%	9%	8%	9%	9%	10%	6%	8%

Corrosion Mapping Visualization Using the Corrosion Mapping Emulator

Corrosion mapping results are visualized through a color-coded display using the Corrosion Mapping Emulator, a digital application designed to present corrosion severity on equipment via PFDs. The use of the corrosion emulator is illustrated in Figures 3 to 5. Figure 3(a) shows the application's initial interface, allowing users to select a processing unit and the crude oil type to be analyzed. Figure 3(b) displays nine predefined potential damage mechanisms based on crude oil characteristics and operational conditions. The application performs automated calculations to identify the most dominant damage mechanism based on the severity level. Results are visualized through color codes on the PFD, as shown in Figure 3(c), which act as visual indicators to establish equipment handling priorities. The data input process was carried out

in excel by incorporating impurity values derived from laboratory analysis and simulation. Beyond the primary visualization, the application includes additional features such as the Equipment List, Piping List, and Dashboard Summary, as shown in Figure 4(a). These features provide detailed equipment data, including equipment name, tag number, material type, color status, and direct reference to the corresponding section in the PFD. All data can be exported as a color-coded PFD reflecting the corrosion evaluation results. The Dashboard Summary overviews identified damage mechanisms and their mapped severity. Hovering over specific colored areas on the equipment reveals photographs and information about the associated damage mechanism. A double-click on equipment opens an interactive dialogue box displaying datasheets, impurity data, corrosion rates, and the current severity classification as shown in Figure

Innovation in Inspection Planning Using the Corrosion Assessment Information System (CAIS) Analytical Tool to Prevent Stationary Equipment Failure in Crude Distillation Unit (CDU) (Muki Satya Permana et al.)

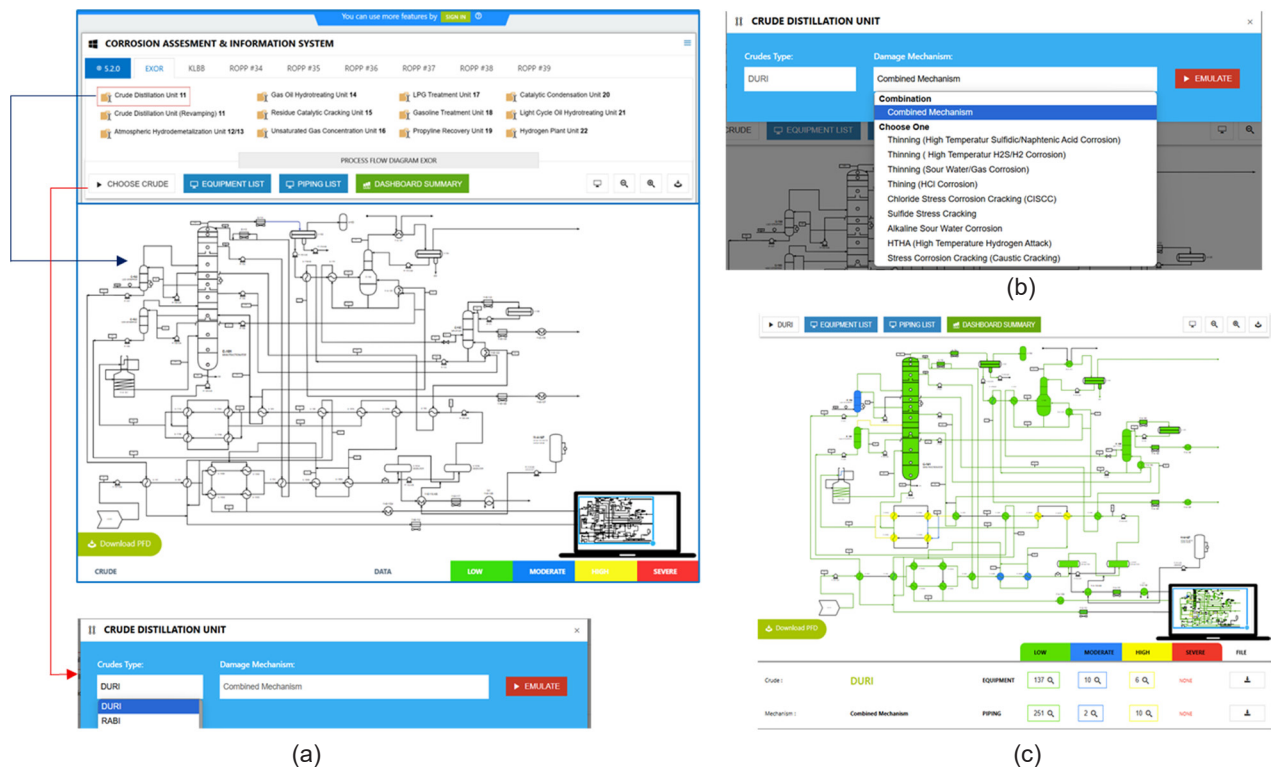


Figure 3. (a). Visualization of the CDU Emulator and PFD (b). Nine types of damage mechanisms displayed in the Emulator (c). Example of color mapping on each equipment on PFD based on Emulator calculations in the CDU unit.

4(b). For equipment classified as “severe” (red), users can simulate changes in operational conditions, impurity variations, or alternative materials. These simulations adjust the corrosion severity and help determine safer operational scenarios. Hence, the emulator acts as a data-driven decision-support tool for corrosion risk mitigation. Users can also record analysis outcomes, field observations, or technical recommendations in a note section.

Additionally, historical records stored in the library, including failure analysis reports and technical drawings, are accessible directly via the interface as shown in Figure 5(a). Double-clicking equipment icons provides detailed datasheets, impurity data, corrosion rates, damage mechanisms, photographs, technical notes, failure history, previous reports, and engineering drawings. Users may periodically update impurity content, enabling real-time visualization of changes in equipment color status. This functionality supports predictive monitoring and improves responsiveness and accuracy in inspection planning.

Enhancing Corrosion Monitoring Efficiency through the CAIS Emulator in Refinery Systems

Traditionally, corrosion monitoring in refinery systems follows the Risk-Based Inspection (RBI) approach (Teurupun et al., 2024), evaluating equipment risks based on damage mechanisms from process stream impurities. However, this approach faces limitations, particularly as data updates are only possible during unit shutdowns, and updates must be performed individually for each piece of equipment, consuming substantial time and resources. To address these limitations, the CAIS Emulator was developed to provide greater flexibility in monitoring. The system offers several technical advantages: 1). Full Unit and Individual Equipment Simulation Capabilities. CAIS allows direct corrosion simulations on entire processing units or specific equipment. It also enables scenario modeling for new crude oil usage without unit shutdowns; 2). Time-Efficient Data Processing. Input impurity data for each process stream can be used to execute simulations quickly. The entire process,

including input and simulation, takes approximately 10 minutes. A single simulation run provides corrosion rate estimations for nine different damage mechanisms; 3). User-Friendly Interface. Designed with an intuitive interface, users can input impurity data and instantly obtain corrosion rate results for all equipment in a unit, visualized on the PFD. The color scheme enables quick visual identification of corrosion severity; 4). High Accessibility and Continuous Availability. CAIS is accessible at any time, especially when impurity content changes. This makes it ideal for both routine monitoring and emergency response; 5). Adaptive to Process Change. CAIS is adaptable, allowing the addition of new corrosion models tailored to different crude oils or products. Model updates and configuration changes can be performed easily without complex structural modifications. These features accelerate

and simplify the corrosion monitoring process and improve decision-making accuracy for asset integrity management. The system holds strong potential for integration into real-time RBI strategies and supports predictive maintenance implementation in the oil and gas industry.

Implementation of cais as an integrated support system for corrosion monitoring and evaluation

The deployment of CAIS has significantly improved the effectiveness of corrosion monitoring and control by stakeholders at PT KPI RU VI Balongan, Indonesia. For corrosion engineers, CAIS is a primary tool for monitoring and reporting corrosion issues, highlighting damage mechanisms, severity levels, damage modes, suspected equipment, and inspection recommendations via periodic reports and email highlights. For production teams, process engineers, inspection teams, and maintenance

Show **10** entries Search:

↑	No.	Tag Number	Mechanism	Status	PFD
	1.	11-F-101 Radiant	Thinning (High Temperature Sulfidic/Naphtenic Acid Corrosion)	Moderate	
	2.	11-F-101 Convection	Thinning (High Temperature Sulfidic/Naphtenic Acid Corrosion)	Low	
	3.	11-C-101 Top 12	Not Susceptible	Not Susceptible	
	4.	11-C-101 Tray 1	Not Susceptible	Not Susceptible	

(a)

Type	:	Shell	Fluids	:	Liquid
Pressure Kp/cm ² G	:		Fase	:	Hidrokarbon
Design Kp/cm ² G	:	32	Type	:	
Operation Kp/cm ² G	:	0.86	Composition / Impurities	:	
Temperature	:		Crude	:	DURI
Design °C	:	305	Sulfur	wt%	0.148
Operation °C	:	259.2	TAN	mg/KH/g	1.6298
Diameter (mm)	:	1480	H ₂ O	wt%	0.02
Thickness Design (mm)	:	156	H ₂ S	wt%	-
Operation	:		H ₂	%-mol	-
Years of operation (mm)	:	1994	CO ₂	%	-
Long operation (mm)	:	31	NaOH	wt%	-
	:		pH	:	-
	:		Cl	ppm wt%	-
	:		NH ₃	wt%	-
	:		NH ₄ HS	wt%	-
Current Mechanism Corrosion					
Thinning (High Temperature Sulfidic/Naphtenic Acid Corrosion)					
Material	:	A-516-GR 70			
Corrosion Rate	:	0.64			mm/yr
State	:	High			
Type of Damage	:	General / Local			
Damage Conditions	:	General (TAN < 0.5) Local (TAN > 0.5)			
Mitigation	:	If colors show Yellow or Red. Please select the Operational Condition and/or the Material available in this Dialogue Box until the color is green			

(b)

Figure 4. (a) Equipment list in Emulator (b) Dialogue box containing datasheet, impurities, and corrosion rate.

divisions, CAIS is the leading platform for integrity operating window (IOW) monitoring, process evaluations, temporary repairs, and inspection planning and execution.

Corrosion meetings facilitate collaboration between corrosion engineers and area inspectors using CAIS to evaluate issues and recommend corrective, preventive, or continuous improvement actions. For inspection teams, CAIS supports non-destructive testing (NDT) mapping, preparation of NDT requests, and coordination with maintenance teams. Meanwhile, NDT engineers utilize CAIS to execute inspections based on NDT maps, prepare inspection reports, and validate obtained data. Implementing CAIS across various organizational functions has improved equipment condition monitoring accuracy, accelerated technical decision-making, and strengthened cross-functional coordination to ensure operational reliability and asset integrity in refinery environments.

CAIS corrosion emulator implementation strategy

Sustainability

CAIS has been consistently implemented as part of the monthly corrosion reporting system at Refinery Unit VI (RU VI) Balongan. This reflects a committed effort toward digital-based corrosion management. Implementing CAIS into organizational working procedures (*Tata Kerja Organisasi* or *TKO*) as a core element of the corrosion management system (CMS) demonstrates high adoption levels and a systematic approach to technology deployment. The central management of PT Kilang Pertamina Internasional (KPI) has recognized its success and recommended replication across all refinery units as a corporate

standard for corrosion risk management.

Standardization

To support implementation and replication, TKO Document No. B04-001//KPI49142/2025-S9 was issued, formally setting the standard for CAIS-based CMS execution across KPI. This includes procedures, responsibilities, and key performance indicators. The independent agency PT LAMERICAN petroleum institute —Institut Teknologi Bandung (ITB) has conducted technical validation of CAIS simulation functions to ensure data integrity, simulation accuracy, and alignment with actual operational conditions, thereby reinforcing CAIS's scientific legitimacy.

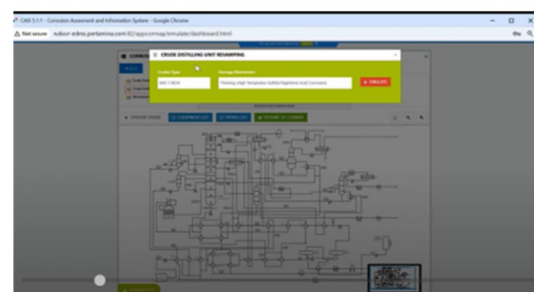
Training and communication

Comprehensive technical training and outreach programs have been carried out across KPI to ensure user competency and broaden system utilization, as shown in Figure 5(b). These cover CAIS interface usage, result interpretation, and data integration with existing inspection management systems. Internal communication initiatives align cross-functional understanding between production teams, process engineers, inspection units, maintenance, and corrosion engineers. This initiative promotes a data-driven collaborative culture and supports timely and accurate decision-making in asset integrity management. This multi-faceted approach, emphasizing sustainability, standardization, and human capacity enhancement, forms the backbone of successful CAIS adoption and integration in the oil refining industry. The results illustrate that structured and adaptive digital tools can significantly transform predictive maintenance and risk-based inspection practices.

MAIN FRACTIONATOR 11-C-101 BOTTOM

DETAILS	CORROSION MECHANISM	PHOTO	NOTE	HISTORY	REPORTS	DRAWING
Show 10 entries						
#	NO. SURAT	PERIHAL				
1.	084/KP49142/2025-S5	Laporan Hasil Pemeriksaan Line Pipe Overhead System Column Main Fractionator 11-C-101				
2.	1266/KP49142/2024-S5	Permintaan Pemasangan Scaffolding Pada Equipment dan Piping Stream Overhead Main Fractionator 11-C-101				
3.	062/KP49142/2023-S5	Hasil Monitoring Thickness Measurement Pada Stream Overhead Main Column 11-C-101 dan Splitter 11-C-105				
4.	1242/E16142/2020-S5	Rekomendasi Penggantian Insulation Bottom Column 11-C-101				
5.	1147/E16142/2018-S5	Laporan Pit Stop Agustus 2018 Hasil Pemeriksaan Main Fractionator 11-C-101				
6.	375/E16142/2018-S5	Hasil Pemeriksaan Line 11-PL-118-A1A1-10"-PP-25 (Line TRA to 11-C-101)				
7.	1550/E16143/2014-S5	Pemeriksaan border 11-C-101				
8.	2184/E16143/2013-S5	PCM Oktober 2013 Laporan hasil pemeriksaan Main Fractionator 11-C-101				
9.	1319/E16143/2013-S5	Hasil pemeriksaan thickness line overhead 11-PG-0601-A1A2M-28"-PP25 & 11-P2-0901-A1A4M-8"-N1 dan 11-C-101 s/d 11-V-102				
10.	0969/E16143/2013-S5	Line corrosion inhibitor di overhead column 11-C-101 Buntu notif no. 2100064407				
Previous		1	2	3	Next	

(a)



(b)

Figure 5. (a) History record (b) Sharing of CAIS with PT KPI.

CONCLUSION

This study successfully developed and implemented CAIS, an analytical tool designed to assess and visualize corrosion severity in oil refinery equipment. CAIS enables American petroleum institute d, color-coded visualization of corrosion risk across process flow diagrams, supporting timely inspection and maintenance prioritization decision-making. The system integrates American petroleum institute 581-based corrosion modeling with real-time input of impurity content and operating conditions, offering flexibility and adaptability across various units and crude oil types. The Corrosion Mapping Emulator within CAIS enhances monitoring capabilities by providing detailed equipment-level insights, scenario simulations, and historical and technical documentation access. CAIS significantly improves time efficiency, data accessibility, and user interaction to support RBI. It also facilitates predictive monitoring and real-time responses to changes in process conditions. Moreover, CAIS has proven effective as a coordination platform for corrosion engineers, inspectors, and maintenance personnel, enhancing cross-functional collaboration and asset integrity management. Implementing CAIS represents a strategic advancement in digital corrosion monitoring, offering a scalable, efficient, and technically robust solution to support reliability and operational excellence in the oil refinery environment.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
API	American Petroleum Institute Corrosion	
CAIS	Assessment	

KPI	Information System Kilang Pertamina Internasional	
RBI	Risk-Based Inspection	
TAN	Total Acid Number	mgKOH/g
LGO	Light Gas Oil	
HGO	Heavy Gas Oil	
CDU	Crude Distillation Unit	
HTSNA	High-Temperature Sulfidic/Naphthenic Acid	
HTHA	High-Temperature Hydrogen Attack	
PFD	Process Flow Diagram	

REFERENCES

- Abdulwahab, N. H., Abed, A. A., & Jaber, M. A. (2022). Real-time remote monitoring and control system for underground pipelines, *International Journal of Power Electronics and Drive Systems*, 12(5), pp. 4892-4092.
- American Petroleum Institute. 2011. American petroleum institute Recommended Practice 571: Damage Mechanisms Affecting Fixed Equipment in the Refining Industry (2nd ed.). Washington, DC: American petroleum institute Publishing Services.
- American Petroleum Institute. 2016. American petroleum institute Recommended Practice 581: Risk-Based Inspection Technology (3rd ed.). Washington, DC: American petroleum institute Publishing Services.
- Antonyuk, E. M., Varshavskiy, I. E., & Antonyuk, P. E. (2019). Adaptive Automatic Monitoring System with Forced Polling of a Low-Active Channel, *IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus)*, Saint Petersburg and Moscow, Russia, 28-31 January, 2019.
- Arena, E., Fargione, G., Giudice, F., & Latona, E. (2022). RBI-IOWs integrated approach to risk assessment: Methodological framework and application, *Journal of Loss Prevention in The*

- Process Industries, 79(104838), pp. 1-15.
- Balasubramanian, V., Chhajaj Jain, M., Golovin, K., & Zarifi, M. H. (2023). Real-time Non-Destructive Erosion Monitoring of Coatings using Passive Microwave Split Ring Resonator Sensor, IEEE International Conference on Consumer Electronics, Las Vegas, USA, 06-08 January, 2023.
- Fuad, M., 2013, Simulasi Distribusi Titik Didih Distilasi TBP dan Hempel Menggunakan Model Matematika Riazzy, Lembaran Publikasi Minyak dan Gas Bumi, 47(1), pp. 49-58.
- Hameed, A, 2016, Risk-based shutdown inspection and maintenance for a processing facility, Process Safety and Environmental Protection, 100, pp. 9-21.
- Hatamov, A. (2022). Disadvantages of the corrosion process and methods of combating corrosion. Proceedings of Azerbaijan High Technical Educational Institution.
- Khan, M. A. A., Irfan, O. M., Djavanroodi, F., & Asad, M. (2022). Development of Sustainable Inhibitors for Corrosion Control, Sustainability, 14(15), pp. 1-17.
- Liao, K., Qin, M., Wang, M., Zhang, S., Wu, L., & Yang, N. (2023). Probing pipe flow impact corrosion monitoring effectiveness under corrosion monitor coupons conditions, Fuel, 353, 129288.
- Lucia, A. (2011). Extraction of naphthenic acid from indonesian crude oils by methanol-ammonium solution. Scientific Contributions Oil and Gas, 34(1), 91-94. <https://doi.org/10.29017/SCOG.34.1.795>.
- Mohammed, A.I., Abdulla, T.A., & Hussein, A.O. (2024). Steady State Simulation and Analysis of Crude Distillation Unit at Baiji Refinery, Journal of Petroleum Research and Studies. 14(1), pp. 131-153.
- Ondinde, P., Ezeifedi, H., Akanni, J., Anyachor, N., Oladipo, A., Ohia, C., Orajiaka, C., Sangoyinka, H., & Onuorah, C. (2023). Corrosion Management Framework: A structured Approach to Managing Corrosion in Oil and Gas Facilities, Gas & Oil Technology Showcase and Conference, Dubai, UAE, March 2023.
- Pertamina. (2024). Failure incident report: Corrosion-related failures in CDU Unit. Technical Documentation, PT Kilang Pertamina Internasional RU VI, Balongan, Indonesia.
- Popova, K., Montemor, M.F., Prosek, T. (2024). Application of Resistometric Sensors for Real-Time Corrosion Monitoring of Coated Materials, Corrosion and Materials Degradation, 5(4), pp. 573-592.
- Qin, C., Dai, L., & Zhu, Y. (2023). A Real-time Corrosion Monitoring Method Based on Quartz Crystal Microbalance, E3S Web of Conferences, 375(03008), pp. 1-4.
- Ramachandran, S. (2017). Advances in monitoring technologies for corrosion inhibitor performance. In M. El-Sherik (Eds), Trends in Oil and Gas Corrosion Research and Technologies, pp. 471-487. Woodhead Publishing Series in Energy.
- Teurupun, A., Nugroho, B. S., Nurrahmana, A., & Alfari, K. (2024). Risk-Based Inspection Analysis of American petroleum institute 581 Pressure Safety Valve & Stripper Acid Gas Removal Unit at PT XY. Scientific Contributions Oil and Gas, 47(3), 313-325. <https://doi.org/10.29017/SCOG.47.3.1645>.
- Wang, S., Limin, W., Cheng, Y., Pengcheng, C., & Hao, W. (2020). Failure analysis: Sulfur stress corrosion cracking of S30432 stainless steel in the final super-heater, Engineering Failure Analysis, 118, 104859.
- Wright, R. F., Lu, P., Devkota, J., Lu, F., Ziomek-Moroz, M., & Ohodnicki, P. R. (2019). Corrosion Sensors for Structural Health Monitoring of Oil and Natural Gas Infrastructure: A Review, Sensors, 19(18), pp. 1-32.
- Yang, X., Liu, M., Liu, Z., Du, C., & Li, X., 2020., Failure analysis of a 304 stainless steel heat exchanger in liquid sulfur recovery units, Engineering Failure Analysis, 116, 104729.
- Zavala, E. (2017). Towards Adaptive Monitoring Services for Self-Adaptive Software Systems. Service-Oriented Computing – ICSOC 2017

Workshops.

Zurkanain, M. A., & Subramaniam, S. K. (2023).
Investigation and Implementation of IoT
Based Oil & Gas Pipeline Monitoring System,
International Journal of Recent Technology and
Applied Sciences, 5(1), pp. 1-11.