BACHELOR THESIS – ME184841

WEB-BASED APPLICATION FOR RISK-BASED INSPECTION ANALYSIS OF GAS PIPING SYSTEM AT CENTRAL PROCESSING FACILITY OF PT X

BAHIEJ AN NAJMU TSAQIB

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ADVISORS:

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UNDERGRADUATE DOUBLE DEGREE PROGRAM

DEPARTMENT OF MARINE ENGINEERING

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APLIKASI BERBASIS WEB UNTUK ANALISIS INSPEKSI BERBASIS RISIKO PADA SISTEM PERPIPAAN GAS DI FASILITAS PEMROSESAN SENTRAL PT X

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FAKULTAS TEKNOLOGI KELAUTAN

INSTITUT TEKNOLOGI SEPULUH NOPEMBER

SURABAYA

2023

APPROVAL SHEET I

WEB-BASED APPLICATION FOR RISK-BASED INSPECTION ANALYSIS OF GAS PIPING SYSTEM AT CENTRAL PROCESSING FACILITY OF PT X

BACHELOR THESIS

Submitted to fulfill one of the requirements

For obtaining a bachelor's degree in Engineering at

Undergraduate Study Program of Marine Engineering

Department of Marine Engineering

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

By: **BAHIEJ AN NAJMU TSAQIB**

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Approved by Hochschule Wismar Germany:

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Representative : Wolfgang Busse, Dr-Ing.
Date : 26th of July 2023

Approved by Head of Marine Engineering Department:

Signature : ....

Head of Department : Beny Cahyono, S.T, M.T., Ph.D.
NIP. /NPP. : 197903192008011008
Date : 26th of July 2023

APPROVAL SHEET II

WEB-BASED APPLICATION FOR RISK-BASED INSPECTION ANALYSIS OF GAS PIPING SYSTEM AT CENTRAL PROCESSING FACILITY OF PT X

BACHELOR THESIS

Submitted to fulfill one of the requirements

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By: **BAHIEJ AN NAJMU TSAQIB**

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2. Dr. Nurhadi Siswantoro, S.T., M.T. — Co-advisor
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SURABAYA

July, 2023

STATEMENT OF ORIGINALITY

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Department	:	Marine Engineering
Advisor	:	Ir. Dwi Priyanta, M.SE.
		Dr. Nurhadi Siswantoro, S.T., M.T.

Hereby declare that the Bachelor Thesis with the title of "WEB-BASED APPLICATION FOR RISK-BASED INSPECTION ANALYSIS OF GAS PIPING SYSTEM AT CENTRAL PROCESSING FACILITY OF PT X" is the result of my own work, is original, and is written by the following the rules of scientific writing.

If in the future there is a discrepancy with this statement, then I am willing to accept sanctions in accordance with the provisions that apply at Institut Teknologi Sepuluh Nopember.

Acknowledged,

Surabaya, 26th of July 2023

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Ir. Dwi Priyanta, M.SE.	Dr. Nurhadi Siswantoro, S.T., M.T.	Bahiej An Najmu Tsaqib
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ABSTRACT

WEB-BASED APPLICATION FOR RISK-BASED INSPECTION ANALYSIS OF GAS PIPING SYSTEM AT CENTRAL PROCESSING FACILITY OF PT X

Student Name / NRP	**:**	**Bahiej An Najmu Tsaqib / 04211941000049**
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Abstract

The oil and gas industry is one of many other types of businesses that always maintain their facilities and assets. Judging from the number and variety of types of equipment, material and construction equipment, piping and instrumentation diagrams, and process flow diagrams, oil and gas companies have complexity in both their operating and maintenance activities. Asset Integrity Management (AIM) is here to help improve the quality of care for company assets. One method of asset maintenance is Risk-Based Inspection Analysis. In this study, a Web-Based Application will be made that is used to conduct RBI Analysis only on gas piping systems at a Central Processing Facility of PT X. The basis for making this application is API RP 580, RBI analysis conducted by the author based on API RP 581, and opinions and recommendations from supervisors. In the RBI analysis conducted before the application design, a probability of failure score of 3.52E-05 with category 2 (Unlikely), a consequence of failure score from the consequence area of 1577,805 ft² with category C (Moderate), a risk score of 0.055 ft² / year with a risk level of 2C (Medium), as well as the results of the inspection in the form of an inspection plan date of March 24, 2036, and recommendations for further inspection. It is expected that this Web-Based Application can make it easier for companies to conduct RBI analyses and improve the quality of asset management. The output of RBI analysis through Web-Based Application is the result of probability and consequence of failure calculations, risk analysis results, and inspection planning in the form of inspection schedules and recommendations.

Keywords: ***Risk-Based Inspection, Web-Based Application, Asset Integrity Management, Central Processing Facility, Gas Piping System***

ABSTRAK

APLIKASI BERBASIS WEB UNTUK ANALISIS INSPEKSI BERBASIS RISIKO PADA SISTEM PERPIPAAN GAS DI FASILITAS PEMROSESAN SENTRAL PT X

Nama Mahasiswa / NRP	:	**Bahiej An Najmu Tsaqib / 04211941000049**
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Abstrak

Industri minyak dan gas adalah salah satu diantara banyak jenis bisnis yang selalu menjaga fasilitas dan aset yang dimiliki. Dilihat dari jumlah dan variasi jenis equipment, material dan konstruksi equipment, piping and instrumentation diagram, dan process flow diagram, perusahaan oil and gas memiliki kompleksitas dalam aktivitasnya baik aktivitas operasi maupun perawatan. Asset Integrity Management (AIM) hadir untuk membantu meningkatkan kualitas perawatan dari aset perusahaan. Salah satu metode dalam perawatan aset adalah Risk-Based Inspection Analysis. Dalam penelitian ini akan dilakukan pembuatan Web-Based Application yang digunakan untuk melakukan RBI Analysis hanya pada sistem perpipaan gas di sebuah Central Processing Facility PT X. Dasar pembuatan aplikasi ini adalah API RP 580, analisis RBI yang dilakukan oleh penulis berdasarkan API RP 581, dan pendapat serta rekomendasi dari para dosen pembimbing. Dalam analisis RBI yang dilakukan sebelum perancangan aplikasi, didapatkan nilai probability of failure sebesar 3.52E-05 dengan kategori 2 (Unlikely), nilai consequence of failure dari consequence area sebesar 1577.805 ft^2 dengan kategori C (Moderate), nilai skor risiko sebesar 0.055 ft^2/year dengan level risiko 2C (Medium), serta hasil dari inspeksi berupa inspection plan date pada 24/03/2036 dan rekomendasi untuk inspeksi selanjutnya. Diharapkan dengan adanya Web-Based Application ini dapat memudahkan perusahaan untuk melakukan Analisis RBI dan meningkatkan kualitas manajement aset. Keluaran dari analisis RBI melalui Web-Based Application ini adalah hasil perhitungan probability and consequence of failure, hasil analisis risiko dan perencanaan inspeksi berupa jadwal dan rekomendasi inspeksi.

Kata Kunci: ***Risk-Based Inspection, Web-Based Application, Asset Integrity Management Central Processing Facility, Gas Piping System***

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With the praise and gratitude, the author conveys to Allah Subhanahu Wa Ta'ala for His grace, the author was able to finish this bachelor thesis with the topic of "Web-Based Application for Risk-Based Inspection Analysis of Gas Piping System at Central Processing Facility of PT X" in time as a requirement to obtain the Bachelor Degree in Marine Engineering Department, Institut Teknologi Sepuluh Nopember - Hochschule Wismar, Germany. Furthermore, the author would like to thank all parties who have given their support and contribution to the author in finishing this bachelor thesis, especially for:

1. Mr. Herman Antono and Mrs. Sri Mulatsih, the author's beloved parents who always give their best support and prayer through ups and downs, and Naura Atika Tsaqib, the author's sister.
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7. Everyone who has helped the author in the completion of this bachelor thesis which cannot be mentioned one by one.

The author hopes this research could be helpful for the development of the Indonesian maritime industry and could provide great insights for the readers. The author is also aware that this bachelor thesis is far from perfect, and critics and suggestions are expected to be added for future research.

Surabaya, 26th of July 2023

Bahiej An Najmu Tsaqib

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CHAPTER 1 INTRODUCTION

1.1 Research Background

One of the energy sources that until now is still widely needed and utilized in Indonesia is natural gas. Based on the Ministry of Energy and Mineral Resources evaluation results in the 2021 SKK Migas annual report, there are currently a total of 24 natural gas resource points spread across various regions in Indonesia with reserves of 285.3 TcF (Trillion Cubic Feet) as can be seen in **Figure 1.1**. Natural gas from these sources flows through pipelines located both under the sea and on land. These are then handed over to several consumer parties, such as power generation companies, petrochemical companies, and other companies that process natural gas into various products, such as LPG, LNG, and CNG as can be seen in **Figure 1.2**.

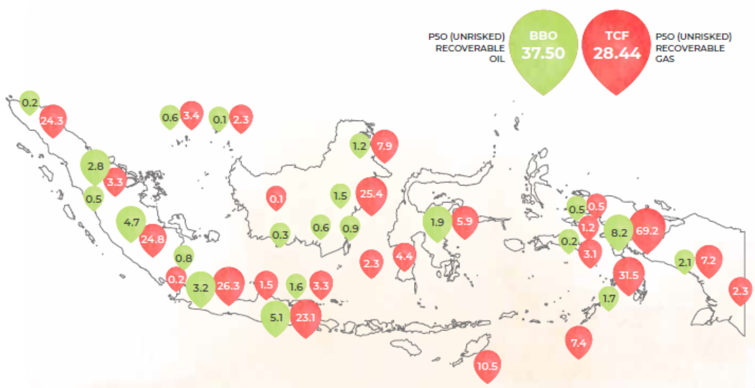

Figure 1. 1 Distribution Map of Oil & Gas Resources in Indonesia (Source: SKK Migas Annual Report, 2021)

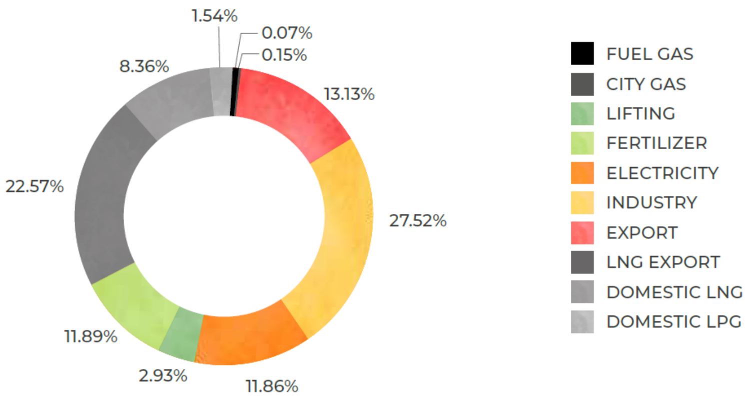

Figure 1. 2 Natural Gas Utilization Percentages (Source: SKK Migas Annual Report, 2021)

The natural gas supply chain system from upstream to downstream has involved many companies and also several facility assets that they have, one of which is Central Processing Facility (CPF). CPF is a critical facility that is instrumental in the extraction, processing, and initial treatment of crude oil and natural gas. In other words, this CPF has a role as a processor of natural gas from offshore and onshore exploitation wells and then forwards it to consumers. In the CPF itself, there are many assets or supporting equipment that have their respective functions, such as storage tanks, pressure vessels, pressure relief devices, separators, and those that connect these types of equipment, namely the piping system.

Seeing that there are many assets in CPF, Asset Integrity Management (AIM) needs to be done as an effort by asset owners/managers to maintain their assets, especially to avoid equipment failures caused by several causes. More specifically, AIM aims to maintain and optimize the use of assets in order to carry out their functions effectively and efficiently while protecting health, safety, and the environment.

One of the causes that pose a threat to company assets is material deterioration or corrosion. For example, pressurized equipment corrosion, such as gas piping systems, can cause leaks that can eventually lead to explosions and fires. In Asset Integrity Management (AIM), one of the risk assessment methods that can be done to prevent this from happening is to use the Risk-Based Inspection (RBI) method. So far, RBI analysis is mostly done by calculating the Probability of Failure (POF) and Consequence of Failure (COF) in Microsoft Excel or using some RBI software that is already widely available.

Asset integrity management of a facility's piping system entails accurately predicting its condition to operate and maintain it at the lowest overall cost. Data management, model implementation, and information visualization are key components in the comprehensive asset management of the piping system. This research creates a centralized web-based platform where models and tools can run, retrieve data, and publish the results for visualization and querying. The report illustrates various aspects of developing a web-based application for store, collect, and analyze the RBI analysis based on API RP 580 and API RP 581. To perform RBI analysis on this webapplication, there are several requirement data and information so that in the end some of the results obtained by users are such as the score and category of probability of failure, score and category of consequence of failure, risk score, risk level based on risk matrix, RBI plan date, and recommendations for the next inspection.

1.2 Problem Statement

Based on the background above, the problem of this study is:

1. How to calculate the Probability of Failure (POF) and Consequence of Failure (COF) of gas piping system based on Risk-Based Inspection (RBI) method?
2. How to determine the Risk Analysis of the gas piping system at Central Processing Facility (CPF) of PT X?
3. How to determine the planning of the inspection strategy and the exact inspection interval of the gas piping system based on the Risk-Based Inspection (RBI) method?
4. How to create a web-based application for Risk-Based Inspection (RBI) analysis of gas piping system at Central Processing facility (CPF) of PT X?

1.3 Research Objectives

Based on the formulation of the problem above, the objectives of this study are:

1. To determine the Probability of Failure (POF) and Consequence of Failure (COF) of gas piping system based on the Risk-Based Inspection (RBI) method

2. To determine the Risk Analysis of the gas piping system at the Central Processing Facility (CPF) of PT X
3. To determine the planning of the inspection strategy and the appropriate inspection interval of the gas piping system based on the Risk-Based Inspection (RBI) method
4. To create a web-based application for Risk-Based Inspection (RBI) analysis of gas piping system at Central Processing Facility (CPF) of PT X

1.4 Scope of Research

The scope of research of this bachelor thesis are:

1. The asset data in this Risk-based Inspection analysis taken from one of the Central Processing Facility (CPF) managed by one of the companies in Indonesia
2. The type of equipment that RBI analysis performs is only the piping system
3. This risk-based inspection analysis is guided by API RP 580 (Risk-Based Inspection) and API RP 581 (Risk-Based Isnpection Methodology)
4. This web-based application is made by using native programming (without framework), choose Laragon as the local-host server and shared hosting as the web hosting type.

1.5 Research Benefit

The benefits that can be obtained from this research are:

1. The website can be used for collecting and storing asset data, analyze RBI analysis of gas piping system at CPF of PT X, and inform the results
2. Can be used as a consideration for companies in determining the priority of inspection implementation as a preventive effort to minimize failures
3. Can be used as a consideration for making decisions in implementing inspection programs and financing inspections
4. Can identify repair or replacement needs of deteriorated equipments
5. Increase the level of safety for workers and the environment.

CHAPTER 2 LITERATURE REVIEW

2.1 Problem Overview

In the oil and gas industry, asset maintenance is one of the main priorities so that production support equipment can work properly and as it should. Of the many types of equipment that need to be maintained are pipes. Pipes are very valuable because, as a transmission line, the movement of fluids, both oil and gas, from one place to another. In reality, not a few incidents of accidents in the field are caused by leaks in pipes due to corrosion. The consequences of this leak are fatal. Apart from the company suffering losses, the leaked fluid can generate sparks, causing explosions and fires. An example of an incident is the explosion and fire at the Conoco Humber Refinery saturated gas plant (SGP) on 16th April 2001 can be seen in **Figure 2. 1**.

Figure 2. 1 Explosion at The Conoco Humber Refinery
(Source: Jonathan Carter, et al, 2006)

The primary cause of this incident is corrosion in a section of a 6" pipe elbow, as seen in the **Figure 2. 2**. Several things can be learned, such as (Carter et al., 2006)

1. corrosion of carbon steel piping in sour service tends to be most pronounced in high turbulence areas such as elbows and tees
2. Conduct periodic inspections, and risk assessments such as RBI on operating assets necessary

In the accidents that have occurred in the oil and gas industry, corrosion is not the only cause. Several other causes include weld material failure, equipment failure, excavation damage, incorrect operation, natural force damage, and others. However, corrosion is still a cause that must be considered, as written in one of the journals of petroleum engineering.

Figure 2. 2 The Failed Pipe Elbow Caused by Corrosion
(Source: Jonathan Carter, et al, 200)

According to statistical data of oil and gas accidents in the US from 2010 to 2015, the top three causes of oil pipeline failures are corrosion, pipe/weld material failure, and equipment failure, while the top three causes of gas pipeline failures are pipe/weld material failure, excavation damage, and corrosion. (Dai et al., 2017)

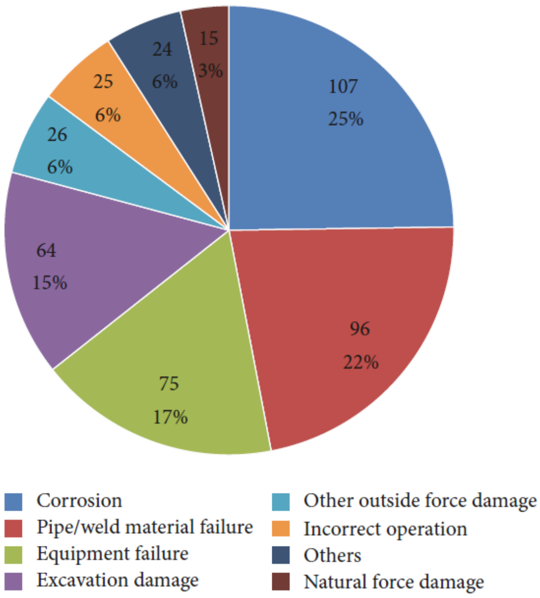

Figure 2. 3 Oil Piping Causes Percentages
(Source: Carter Jonathan, et al, 2017)

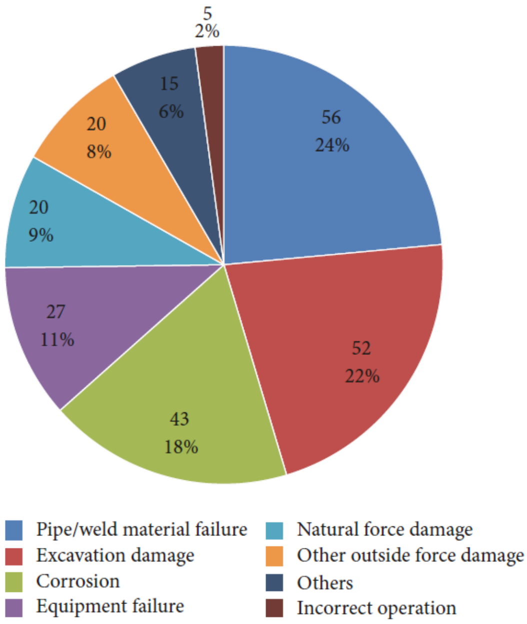

Figure 2. 4 Gas Piping Causes Percentages
(Source: Lianshuang Dai, et al, 2017)

2.2 Related Studies

2.2.1 Risk Assessment in Onshore Pipeline Using Risk-Based Inspection (RBI) Method

This research discusses the risk assessment of the Salawati, West Papua pipeline, which consists of 3 flowlines and one export line. The flowline flows oil from 3 wells to the Matoa Processing Area (MPA) with pipe diameters of 6", 8", and 10". Meanwhile, the export line functions to channel oil from the Matoa Processing Area (MPA) to the Canal Jetty with a pipe diameter of 6". The probability of failure calculation method uses a random number generated using a Monte Carlo simulation. (Prabowo et al., 2019)

At the same time, calculating the probability of failure and determining the level of risk in the pipeline uses a semi-quantitative risk-based inspection analysis based on the API code RP 581. From this research, the reliability of the four pipelines can later provide a systematic analysis of failure mechanisms. So that it can determine the value failure opportunities and broad consequences of the affected areas of the pipeline failure, as well as provide more effective and efficient inspection ideas.

From this study, pipeline risk levels, inspection recommendations, and inspection intervals were generated, which are shown in the **Figure 2. 5** and **Table 2. 1**.

From the analysis and discussion carried out in this study, it can be concluded that each pipeline has different risk level categories and inspection time intervals at each location. Furthermore, this difference is influenced by many aspects analyzed in the Probability of Failure (POF) and Consequence of Failure (COF) sections.

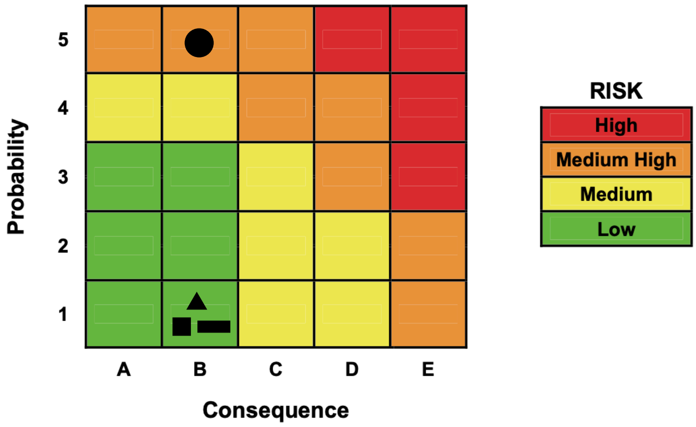

Figure 2. 5 Risk Matrix Result of Related Studies 1
(Prabowo, Risky Lestari, et al. 2018)

Table 2. 1 Inspection Interval Recommendation
(Prabowo, Risky Lestari, dkk. 2018)

Lokasi *Pipeline*	Tingkat Risiko	Waktu Inspeksi (Tahun)
Canal	*Low*	10
Bagong	*Low*	10
MT14	*Low*	10
SWO	*Medium High*	4

2.2.2 Risk Assessment on Gas Piping Against Corrosion Using a Risk Based Inspection API 581

This research was conducted in the gas piping system of the HTSH (High Temperature Superheater) and LTSH (Low Temperature Superheater) rooms at pltu unit three at PT Indonesia Power Semarang. PT Indonesia Power Semarang Generation Business Unit is located in an area of 40 hectares in Tanjung Emas Bay, Semarang. UBP Semarang has an installed capacity of 1,408 MW and consists of three plants. Steam Power Plant (PLTU), Steam Gas Power Plant (PLTGU), Gas Power Plant (PLTG). (Ervando et al., 2015)

The data on the specification of the pipes and other data needed to conduct the research can be seen in **Table 2. 2**, **Table 2. 3**, and **Table 2. 4**.

Table 2. 2 Piping Data
(Satmoko, M. Ervando Among, et al. 2015)

Sampel	Jenis Pipa	Tebal Awal Pipa (mm)	Diameter Pipa (mm)	Umur Pakai Pipa (tahun)
1	SA213T22-01 (HTSH)	6	50,8	5
2	SA213T22-26 (HTSH)	6	50,8	5
3	SA178C-01 (LTSH)	4	57,1	5
4	SA178C-30 (LTSH)	4	57,1	5

Table 2. 3 Inspection and Piping Maintenance Data

(Satmoko, M. Ervando Among, et al. 2015)

No	Jenis Pipa	Sistem Deteksi	Sistem Isolasi	*Thinning Type*	Kuantitas Inspeksi	Kualitas Inspeksi	Sistem Mitigasi
1	SA213T22-01	B	B	*Corrosion*	3	3	*Usually effective*
2	SA213T22-26	B	B	*Corrosion*	3	3	*Usually effective*
3	SA178C-01	B	B	*Corrosion*	3	3	*Usually effective*
3	SA178C-30	B	B	*Corrosion*	3	3	*Usually effective*

Table 2. 4 Operation Condition and Environment Data
(Satmoko, M. Ervando Among, et al. 2015)

No	Jenis Pipa	Jenis Fluida	Tekanan Operasi (KPa)	Temperatur Operasi (°C)	*Corrosion Rate* (inch/year)	*Corrosion Allowance* (inch)	*Inventory* (lbs)
1	SA213T22-01	*steam*	12356	540	0,0048	0,2	1711,02
2	SA213T22-26	*steam*	12356	540	0,0040	0,2	1709,28
3	SA178C-01	*steam*	12356	535	0,0024	0,13	1690,33
4	SA178C-30	*steam*	12356	535	0,0030	0,13	1688, 02

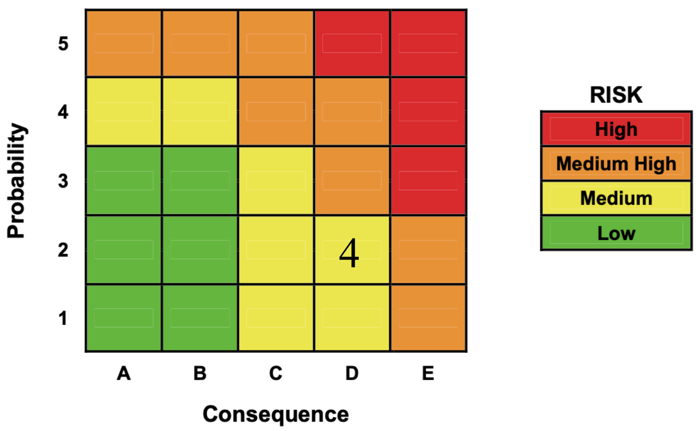

Figure 2. 6 Risk Matrix Result of Related Studies 2
(Satmoko, M. Ervando Among, et al. 2015)

Based on Figure 2. 5, The RBI analysis of the four pipes analyzed places them in 2D positions in the 5X5 semi-quantitative analysis matrix. The four pipes have a medium risk status and require attention on the corrective maintenance scale. Visual inspection, ultrasonic beam, eddy current, leakage flux, radiography, and dimensional measurements are all recommended inspection methods.

2.2.3 Study of Risk-Based Inspection (RBI) Applications on Process Piping Pl-117-A 0.75", 2", 3", And 4" Using API 581 Base Resource Document Method in The Oil and Gas Industry

The object of this research is the process piping PL-117-A 0.75", 2", 3", and 4". Process piping PL-117-A 0.75", 2", 3", and 4" is an oil outlet from a production separator, which has a different pressure and temperature than the environment outside the pipe. (Eric Prasetyo, 2015)

The analysis was carried out using a semi-quantitative method in appendix B API 581 Base Resource Document. So, the results obtained are that pipes with a diameter of 0.75", 2", and 3" have a low level of risk, and no further inspection is needed. However, repairs are carried out. Meanwhile, pipes with a diameter of 4" have a moderate risk level. Repairs must be carried out immediately because the actual thickness of the pipe is lower than the allowable pipe thickness as can be seen in **Figure 2. 7**.

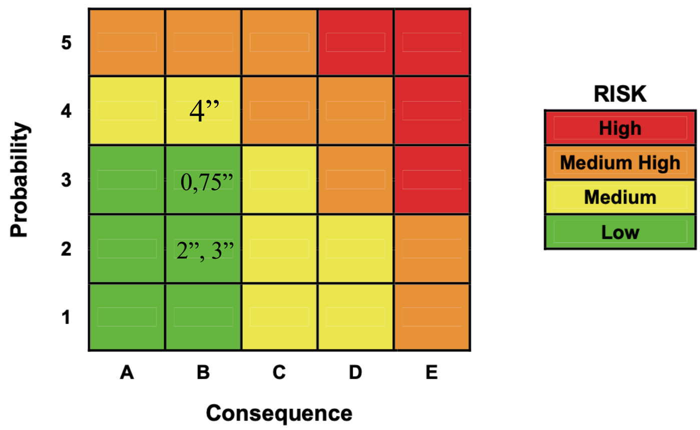

Figure 2. 7 Risk Matrix Result of Related Studies 3
(Prasetyo, Eric. 2015)

2.3 Oil and Gas Business Process

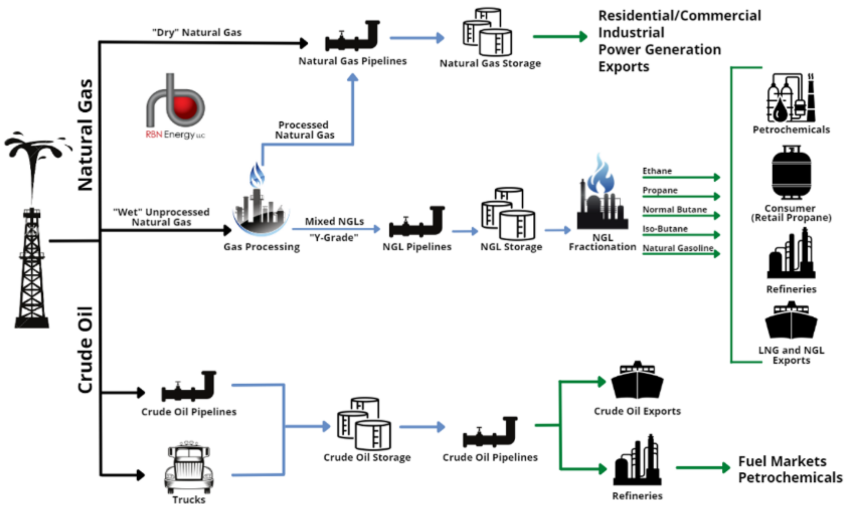

Figure 2. 8 Oil and Gas Business Process
(Source: https://rbnenergy.com)

The oil and gas business process entails a series of activities and operations pertaining to the exploration, production, refinement, and distribution of oil and gas resources. From initial exploration to the ultimate delivery of petroleum products to consumers, a number of stages and parties are involved in this process. Here is an overview of the most important stages in the oil and gas business procedure: (Devold, 2013)

1. Exploration and Revelation
    - Geologists and geophysicists examine geological formations and identify potential oil and gas reserves using seismic imaging and other techniques.
    - Drilling operations are conducted by exploration companies to corroborate the presence of hydrocarbon resources.
    - The company evaluates the extent, quality, and economic viability of the reserves upon discovery.
2. Field Construction and Production
    - After the confirmation of a commercial discovery, field development planning commences. This includes determining the optimal drilling locations, production methods, and infrastructure needs.
    - To extract oil and gas from the reservoirs, wells and production facilities are drilled and installed.
    - Production operations include well performance management, fluid flow regulation, and production level maintenance.
3. Refining and Processing
    - At central processing facilities (CPF), crude oil and natural gas undergo preliminary processing to separate impurities and liquids.
    - Crude oil is transported to refineries, where it endures complex refining processes to produce gasoline, diesel, jet fuel, and lubricants, among other petroleum products.
    - Before being transported through pipelines or converted into liquefied natural gas (LNG) for storage or export, natural gas may be processed to remove impurities, such as sulfur compounds and contaminants such as water and carbon dioxide.
4. Distribution and Transportation
    - Pipelines, tankers, or vehicles transport refined petroleum products to distribution terminals, storage facilities, or consumers directly.
    - Pipelines play a crucial role in the long-distance transport of crude oil and refined products. For transport to remote locations or regions without pipeline infrastructure, tankers and vehicles are utilized.
    - Distribution terminals and storage facilities store and manage inventories of petroleum products, ensuring a steady supply to diverse markets and consumers.
5. Promotion and Sales
    - Oil and gas companies engage in marketing and sales activities to attract customers and promote their products.
    - Petroleum products are supplied to wholesalers, retailers, and final consumers through a variety of channels, such as gas stations, industrial customers, and commercial clients.
    - Contracts and prices are negotiated based on market conditions, the dynamics of supply and demand, and other factors.
6. Safety and Environmental Compliance
    - Throughout the entire oil and gas business process, companies must adhere to environmental regulations and safety standards to mitigate the environmental impact of operations and protect the health of workers and communities.
    - There are measures in place to prevent breaches, control emissions, manage waste, and reduce the environmental impact of operations.

7. Investigation and Development

- Oil and gas companies invest in research and development (R&D) to enhance extraction techniques, refinement processes, and the exploration of alternative energy sources.
- Research and development efforts are concentrated on enhancing operational efficacy, decreasing environmental impact, and developing technologies for healthier and more sustainable energy production.

The oil and gas business process is intricate and requires collaboration among numerous parties, including exploration companies, production operators, refineries, transporters, marketers, and regulators. Effective management and coordination of these activities are essential for the efficient and profitable operation of the industry, while also ensuring environmental stewardship and meeting society's energy requirements.

2.4 Central Processing Facility

In the oil and gas industry, a Central Processing Facility (CPF) is a critical facility that is instrumental in the extraction, processing, and initial treatment of crude oil and natural gas. It is a centralized location where a variety of operations are performed to separate, refine, and prepare hydrocarbon resources for distribution.

A Central Processing Facility's primary function is to receive the production stream from oil and gas wells in a particular field or region. It is designed to handle large volumes of crude oil, natural gas, and associated fluids, and functions as a hub for processing these hydrocarbons.

Figure 2. 9 Central Processing Facility
(Source: https://metenders.com)

Typically, a CPF consists of processing units, equipment, and infrastructure to perform out the following essential functions: (Devold, 2013)

1. Separation
   Oil, natural gas, and water are separated by the CPF. Separators are utilized to separate the various components based on their respective densities, allowing crude oil and natural gas to be processed independently.
2. Oil Processing
   Various processes are used to remove impurities such as water, sediment, and solid particles from crude oil. This process utilizes desalters, dehydration units, and other apparatus to improve the oil's quality and make it suitable for transport.
3. Gas Processing
   Natural gas produced alongside crude oil typically contains impurities, including sulfur compounds, carbon dioxide, and other contaminants. The CPF contains gas processing devices, including gas separators, compressors, and scrubbers, to remove these impurities and prepare the gas for transport or further processing.
4. Preservation and Stabilization
   The CPF provides temporary storage containers and facilities for processed crude oil before it is transported to refineries and other downstream destinations. Additionally, stabilization procedures may be used to reduce the oil's vapor pressure, allowing for safe storage and transport.
5. Measurement and Management
   Quantity and quality measurements of crude oil and natural gas must be precise for commercial transactions and operational control. The CPF is equipped with sophisticated measurement and control systems to monitor and regulate the hydrocarbons' discharge rates, pressures, and temperatures.
6. Utility and Infrastructure Services
   A CPF requires utilities such as power supply, water treatment, and waste management systems to support its operations. In addition, it may contain residential quarters, offices, and maintenance facilities for the personnel responsible for operating and maintaining the facility.

After being processed and treated at the Central Processing Facility, crude oil and natural gas are typically transported via pipelines, tankers, or other means to refineries, petrochemical facilities, or distribution networks for further processing, refining, and distribution to consumers.

Central Processing Facilities are essential components of the oil and gas production infrastructure, as they allow for the efficient and cost-effective processing of hydrocarbon resources, ensuring that they satisfy the necessary quality and transportation standards prior to being sold on the market.

2.5 Gas Piping System

Gas piping system is a network of pipes and associated components designed to transport natural gas or other gases from their source to various locations of use in a safe and efficient manner. Commonly found in residential, commercial, and industrial settings where natural gas is utilized for heating, cooking, and other purposes.

Figure 2. 10 Piping System at CPF
(Source: https://www.codesteel.com)

These are the principal components of a gas piping system: (Folga, 2007)

1. Supply Line
   The supply line connects the gas source, such as a utility gas meter or a gas canister, to the gas distribution system. This line is typically constructed from metal or a flexible material designed to withstand the pressure and passage of the transported gas.
2. Gas Meter
   In residential and commercial structures, a gas meter is installed on the supply line to measure the quantity of gas consumed. The meter records gas consumption, allowing the gas utility company to provide accurate billing.
3. Gas Regulator
   A gas regulator is a device installed at the supply line to regulate and sustain the gas pressure entering the piping system. It ensures that the pressure remains within safe parameters, preventing excessive pressure that could cause appliance damage or pose a safety risk.
4. Piping
   The piping consists of interconnected pipelines that transport gas from the supply line to various points of use, including appliances, heaters, and other gas-powered equipment. Copper, steel, or plastic are common examples of pipe materials that are appropriate for gas transport.
5. Valves
   Valves are essential components for controlling and isolating gas flow within a piping system. Typically, main shut-off valves are installed near the gas meter or at critical building entrances, allowing the gas supply to be completely shut off in the event of an emergency or maintenance. At various locations, additional valves may be installed to regulate gas passage to specific areas or appliances.
6. Connectors
   Connectors are used to join pipelines or connect pipes to gas-powered appliances or equipment. These connectors may consist of fittings, couplings, or adapters designed for gas-specific materials and applications.
7. Venting and Exhaust Systems

Ventilation and Exhaust Systems: Gas-powered appliances frequently generate combustion byproducts that must be safely vented outside of the building. The gas piping system incorporates vent pipelines and exhaust systems to remove exhaust gases, preventing their accumulation and ensuring adequate ventilation.

8. Safety Measures

   Gas piping systems integrate a variety of safety measures to prevent gas leaks, monitor gas levels, and detect potential dangers. These measures may include gas leak detectors, pressure sensors, and emergency shut-off systems that cut off the gas supply automatically in the event of a gas leak or other emergency.

Gas piping systems must be designed, installed, and maintained by qualified professionals in accordance with the applicable building codes, regulations, and safety standards. Regular inspections and maintenance are required to identify and address any potential leakage, corrosion, or other problems that could compromise the system's safety and efficacy.

Proper installation, maintenance, and adherence to safety protocols are required for the safe operation of gas piping systems, minimizing the risk of gas leakage and fire hazards and ensuring the dependable supply of gas to the intended points of use.

2.6 Related Goverment Regulations

Oil and gas companies are obliged to implement safety regulations for each process, which refer to the Government of Indonesia, regulators, and ensure that everything goes well on track and under control. Every worker deserves protection and safety in every detail of the work. Therefore, the implementation of any regulations that refer to occupational safety and health, it is necessary to prevent failures or accidents in any operation.

2.6.1 Undang-undang Republik Indonesia No. 1, 1970

This regulation provides security reasons. As we can see in Chapter III, Section 3, Paragraph 1, explains that in order to realize occupational safety, we need: (Presiden RI, 1970)

1. Prevent and reduce the likelihood of accidents
2. Prevent, reduce and extinguish fires
3. Prevent and reduce the danger of explosion.

2.6.2 Peraturan Pemerintah Republik Indonesia No.11, 1979

This regulation controls the safety of work in the process of refining oil and gas. It consists of 31 chapters and 58 articles regulating the administration and supervision of occupational safety on the refining process of the oil and gas industry, the authority and responsibility of mining ministers, and in the implementation of supervision is conveyed to the Director General (Director General) with the right of substitution while the supervisory duties and work are carried out by the head of inspection. According to Chapter IV of the Article, 14 and 15 discuss the use and program of inspections to be carried out to prevent possible hazards that may occur during the processing of petroleum. (Presiden RI, 2001)

2.6.3 Peraturan Menteri ESDM Republik Indonesia No. 38, 2017

This regulation establishes the regulation of the Minister of Energy and Mineral Resources on the inspection of safety installations and equipment in the business of the oil and gas industry. Some related articles include: (Menteri ESDM, 2017)

1. Section 5 Verse 1
   For the guarantee of design, construction, operation and maintenance, testing, inspection and implementation of installations and equipment, any facilities and equipment used in the activities of the oil and gas business should be properly inspected and inspected.
2. Section 11 Verse 2
   Safety inspections and inspections of the operated installations and equipment can be carried out periodically based on a certain period or time as well as the results of risk analysis.
3. Section 17 Verse 1 and 3
   Approval for the use of periodic security checks based on a certain period is valid for a maximum of four years or less of that period if the installation and equipment change or are in doubt about its capabilities.

2.6.4 Peraturan Menteri ESDM Republik Indonesia No. 18, 2018

The specific content of this regulation is further likely to lead to procedures on how to conduct a safety inspection and the responsible parties carrying out this inspection, as mentioned below: (Menteri ESDM, 2018)

1. Chapter III Section 6 Verse 1 dan 2
   1) Any installation or equipment used in the oil and gas industry must conduct inspections and safety checks.
   2) Types of equipment engaged in the oil and gas industry that must be included in the inspection consist of pressure vessels, rotating equipment (pumps and compressors), power plants, power transformers, distribution panels, atmospheric tanks, etc.
2. Chapter III Section 10 Verse 1 dan 2
   1) The Head of Engineering issues information about the results of the inspection.
   2) The inspection company issues an inspection certificate to replace the description of the inspection results.
   3) If the installation and/or equipment is not put into operation, the Head of Engineering reports to the Head of Inspection.
   4) Least loaded inspection certificate:
      a. User name and owner of the installation or equipment
      b. Type of installation or equipment
      c. Design and operation
      d. Data service life of the safety equipment design
      e. Conclusion inspection results
      f. Validity period accuracy of the handover measuring instrument system (if any).

2.6.5 Work Procedure Guideline 041 SKK MIGAS

SKK Migas is an institution established by the government of the Republic of Indonesia through Presidential Regulation (Perpres) No. 9 of 2013 which discusses the implementation of management in oil and gas activities. SKK Migas is a task by carrying out the administration of the upstream oil and gas business under a cooperation contract and also issuing regulations and procedures as a Work Procedure Guideline (PTK). One of the PTKs that oil and gas companies in Indonesia should pay attention to is about "Maintenance of Oil and Production Facilities". According to PTK-041 / SKKMA000 / 2018 / S0, Chapter II "Principles of

Maintenance Management", Any data and documents related to the maintenane program are periodically checked by the PSC and stored in a data management system that can be updated and accessed at any time. Data and documents related to the maintenance program include data integrity and reliability, including Risk Based Inspection (RBI).(SKK MIGAS, 2021)

2.7 Asset Integrity Management System (AIMS)

The oil and gas industry is full of challenges that can take up a significant amount of time, money, and resources. Asset integrity is defined as an asset's ability to perform its required function effectively and efficiently while safeguarding the health, safety, and the environment. Asset Integrity Management ensures that the people, systems, processes, and resources that deliver integrity are in place, in use, and will perform when needed throughout the asset's entire lifecycle.

Although the risk of a major incident can never be completely eliminated, a systematic delivery and assurance process that improves the asset's overall reliability and performance can significantly reduce the likelihood of occurrence and consequence.

Asset Integrity Management can also be defined as the continuous assessment process used throughout the design, construction, installation, and operation of facilities to ensure that they are and remain fit for purpose. In this context, integrity is defined as preventing fluid or energy from escaping the facilities. (Millar, 2015) The integrity management process encompasses the fluid-containing equipment, the structures that support the equipment, and any other systems that prevent, detect, control, or mitigate a major accident hazard. A loss of integrity (containment) could have a negative impact on personnel safety, asset/facility safety, the environment, or production and revenue.

Theaim of the asset integrity management process is to provide a framework for the following: (Millar, 2015)

1. Compliance with company standards, regulatory and legislative requirements
2. Assurance of technical integrity by the application of risk based or risk informed engineering principles and techniques
3. Delivery of the required safety, environmental and operational performance
4. Retention of the License to Operate
5. Optimization of the activities and the resources required to operate the facilities whilst maintaining system integrity
6. Assurance of the facilities’ fitness for purpose

Some of the contributing factors to the assurance of current and continued asset integrity are represented in the **Figure 2. 11**.

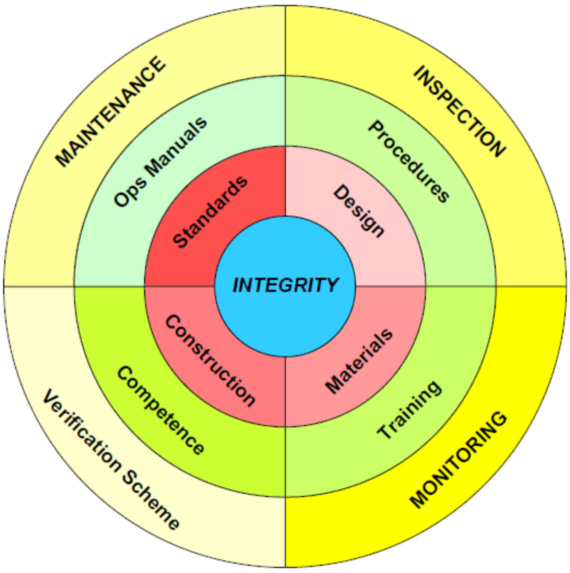

Figure 2. 11 Contributors to Asset Integrity
(Source: Dr. Peter Mcclean Millar, 2015)

2.8 Material Deterioration (Corrosion)

Corrosion is a natural process that describes the deterioration or degradation of materials, particularly metals, as a result of chemical reactions with their environment. It occurs when metals come into contact with substances in their environment, resulting in the progressive deterioration of their structure and properties. (American Petroleum Institute, 2011)

Electrochemical corrosion, which entails the transfer of electrons between a metal and its environment, is the most prevalent type of corrosion. It typically takes place in the presence of an electrolyte, which can be a liquid, such as water or an acidic solution, or even atmospheric moisture. The process of electrochemical corrosion involves two fundamental reactions such as anodic site and cathodic site.

At the anodic site on the surface of the metal, metal atoms lose electrons, resulting in the formation of metal ions (cations). The term for this process is oxidation. While at the cathodic site, which is typically a region with a distinct electrochemical potential, reduction reactions occur. Depending on the environment, this may entail the reduction of oxygen, hydrogen ions, or other substances.

The electrochemical corrosion process is propelled by an electrochemical cell in which simultaneous anodic and cathodic reactions occur. The metal serves as the anode, where corrosion takes place, while another substance, known as the cathode, is responsible for the reduction reaction.

Corrosion in oil and gas piping systems is a major concern due to its potential impact on the infrastructure's integrity, safety, and dependability. These systems transport crude oil, natural gas, and a variety of petroleum products over extensive distances and in a variety of operating conditions. These pipelines' corrosion can cause leaks, malfunctions, and environmental hazards. To preserve the integrity of oil and gas piping systems, it is crucial to comprehend and mitigate corrosion.

Several factors contribute to the corrosion of oil and gas pipelines:

1. Environmental Factors
   The presence of moisture, oxygen, and other corrosive agents in the environment may accelerate corrosion. Underground pipelines may encounter moisture from the soil, whereas above-ground pipelines are exposed to atmospheric moisture and fluctuating weather conditions. In addition, the presence of impurities in the transported fluids, such as hydrogen sulfide (H2S), carbon dioxide (CO2), or chlorides, can exacerbate corrosion.
2. Fluid Composition
   The composition of the transported fluids, such as acidity, salt concentration, and presence of corrosive contaminants, can influence the corrosion rate. As an example, corrosive conditions can be caused by crude oil or natural gas with a high salt or acidic component content.
3. Internal Corrosion
   Due to the corrosive nature of the transported fluids, corrosion can occur within the conduit. This type of corrosion may be caused by chemical reactions, such as the oxidation of metals, or microbiologically influenced corrosion (MIC), which is the consequence of microbial activity in the pipeline.

Figure 2. 12 Piping Internal Corrosion
(Source: https://pipingengineer.com)

4. External Corrosion
   External corrosion can result from the pipeline's contact with the adjacent soil, water, or atmosphere. External corrosion rates can be affected by soil characteristics like moisture content, pH, and corrosive substances.

Corrosion management in oil and gas piping systems requires a comprehensive approach that includes design considerations, preventive measures, regular inspection, and maintenance. By implementing effective corrosion control strategies, the industry can ensure the safe and reliable operation of oil and gas pipelines, minimizing the risk of leaks, environmental pollution, and disruptions in the energy supply chain.

Figure 2. 13 Piping External Corrosion
(Source: https://dynagard.com)

2.9 American Petroleum Institute (API)

The risk-based inspection method based on API RP 580 and 581 determines the inspection program for some equipment, including piping systems. The American Petroleum Institute, or API, is a trade organization representing various oil and natural gas industries in the United States. These standards aim to help users increase efficiency and savings in their business operations while still adhering to statutory regulations, maintaining public safety and health, and maintaining sustainability. American Petroleum Institute (API) Products can be seen in **Table 2. 5**.

Table 2. 5 American Petroleum Institute (API) Products

No.	API *code*	Title
1	API 510	Pressure Vessel Inspection Code-Inspection, Repair, Alteration, and Rerating
2	API 570	Piping Inspection Code-Inspection, Repair, Alteration, and Rerating of Inservice Piping Systems
3	API 579	Fitness-For-Service
4	API 653	Tank Inspection, Repair, Alteration, and Reconstruction
5	API 750	Management of Process Hazards
6	API 752	Management of Hazards Associated With Location of Process Plant Buildings, CMA Managers Guide
7	API 941	Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants
8	API 580	Risk-based Inspection
9	API 581	Risk -based Inspection Methodology

2.9.1 API Recommended Practice 580

API RP 580 is one of the API products with minimum program requirements to meet interval inspection requirements based on RBI versus rule-based requirements analysis. It provides additional recommended guidance for using risk analysis to develop an effective inspection plan. The use of RBI for inspection planning is not mandatory but optional, subject to requirements. (American Petroleum Institute, 2016)

An inspection program is a systematic process that begins with identifying facilities or equipment and ends with an inspection plan. The result of the RBI assessment carried out by this RP is an inspection plan for each part or group of equipment being assessed, which must include the following:

a. Identify the cause of the risk
b. Examination method to be carried out
c. Inspection rate (Percent of total area to be inspected or specific location)
d. Inspection interval or next inspection date (time)
e. Another risk mitigation activities
f. Residual risk level after inspection and other mitigation measures have been implemented.

API 580 guides the development of a Risk-Based Inspection (RBI) program for static equipment such as petrochemical refineries, chemical process plants, and oil and gas production facilities. The aim of API RP 580 is to introduce general principles and minimum guidance for the current RBI. In addition, recommended practices provide a quantitative calculation method for determining inspection plans.

RBI is synonymous with risk priority inspection, inspection with risk information, and inspection planning using risk-based methods. Physical assets are all facilities, components, and systems within the company, including the company's building.

2.9.2 API Recommended Practice 581

API RP 581 regulates risk-based inspection methodologies, providing quantitative procedures for creating inspection programs using risk-based methods for static equipment, including pressure vessels, pipes, tanks, Pressure Relief Devices (PRD), and heat exchanger tubes.

Calculating risks contained in API RP 581 involves determining the probability of failure (POF) combined with the consequences of failure (COF). Failure is defined as loss of resistance from set pressure (limit) resulting in leakage to the atmosphere and rupture of pressurized components. The risk increases as damage accumulate during the operation process. Therefore, the act of inspection alone does not reduce the risk of equipment. However, it does reduce uncertainty and therefore allows a more accurate qualification of the defects present in each component. (American Petroleum Institute, 2016)

2.10 Risk-Based Inspection (RBI)

Risk Based Inspection (RBI) consists of developing an inspection strategy based on failure risk knowledge. The RBI method incorporates the failure probability and the failure consequences to determine the level of risk of the analyzed equipment. The probability of failing a piece of equipment is proportional to the analysis of the likelihood of failure. In contrast, the failure effects analysis focuses on the impact of the failure event.(Siswantoro et al., 2021)

RBI generates optimal inspection planning for the asset and prioritizes inspections from lowest to highest risk. In other words, RBI inspection planning centered on determining what to inspect, how to inspect, where to inspect, and how frequently to inspect. Utilizing inspection planning to control the asset's deterioration will have a significant impact on the system's operation and the company's finances. (Priyanta et al., 2017)

RBI risk analysis on gas pipeline systems uses data on isolated systems' actual operational and structural conditions. In addition, design condition data is also needed. To get a valid information on RBI analysis, it is necessary to validate it to ensure that all data entered is correct. When conducting an RBI risk analysis, we will know the risk level of the system. The gas piping system must be analyzed to determine the level of risk and an inspection plan that is appropriate to the level of risk.

Figure 2. 14 shows the RBI planning process. They start by collecting equipment specification data and inspection histories, such as material characteristics, failure history, current conditions, and other data. (American Petroleum Institute, 2016) Then, the probability of failure and the consequences of failure are calculated. Both can determine the level of risk of each component. After knowing the risks, inspection planning and mitigation (if any) are determined—risk mitigation, such as changes in material construction and operating conditions and the use of corrosion inhibitors.

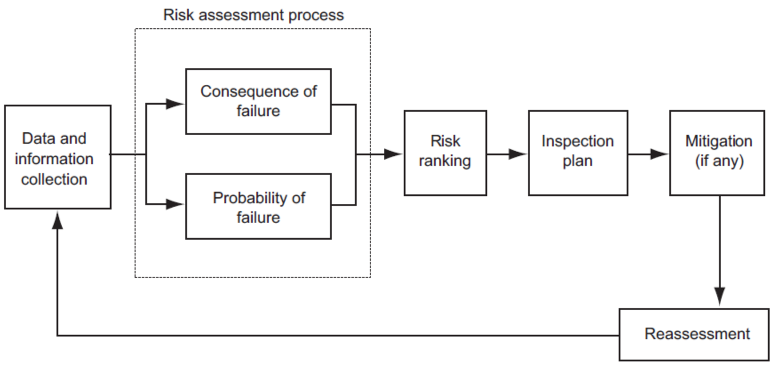

Figure 2. 14 Risk Based Inspection Planning Method
(Source: API RP 580, 2016)

2.10.1 RBI Advantages

The main result of implementing the RBI method is a plan that addresses risk management at the equipment level. The plan considers risks from a safety/health/environmental and economic perspective. (American Petroleum Institute, 2016) Implementation of the plan can result in the following:

1. Reducing the risk of the facility or equipment under study.
2. Increasing the level of safety because it still follows international standards/codes.
3. Determine the equipment that does not require inspection or other mitigation measures.
4. Generate a risk-adjusted inspection plan for the specified component that is cost-effective

2.10.2 RBI Limitation

Even though it has prominent advantages, the application of the RBI method will not be effective if there are deficiencies such as: (American Petroleum Institute, 2016)

1. Inaccurate or incomplete data
2. Inadequate design or faulty installation of equipment.
3. Ineffective implementation of plans.
4. Incompetent team or personnel.

It should be noted that RBI cannot eliminate risk. However, the application of RBI can manage risk at an acceptable level by prioritizing components with a higher risk.

2.10.3 2.10.3 RBI Results

The result of applying the RBI method is an inspection plan for each component in the analyzed system/component according to its risk level, which explains:

1. Applicable inspection methods
2. Time interval until the next inspection
3. Other mitigation measures include a component replacement, component upgrade, replacement of corrosion inhibitors, and other measures per component conditions.

Risk reduction from before and after inspection or mitigation (if any).

2.11 Unified Modeling Language (UML)

In order to create an application, modeling is required. Modeling is identical to designing; the only distinction is that modeling is a form of system implementation that involves putting a design into a diagram.

Using UML (Unified Modeling Language), a programmer can readily comprehend, analyze, and streamline the programming process. Typically, an application program is a system that is utilized and implemented for an extended period of time. In addition to being used at that time, the application program continues or continues to be utilized. Because application programs are used for an extended period of time, it is essential to have a thorough analysis of planning, design, and modeling, such as flow, for application programs.

An effective system begins with a mature design and modeling, as should be noted. One that can be practiced, specifically with UML. The need for UML serves the following functions and purposes: (Haviluddin, 2011)

1. Provides users with a visual or drawing modeling language for a wide range of programming languages and general process engineering.
2. In modeling, incorporate the finest available information.
3. Provide an overview of the model or use it as a language for evocative visual modeling in system development.
4. Not only describes the software system model, but can model object-oriented systems
5. Make it easy for users to comprehend a system.
6. Useful as a blueprint, this will undoubtedly explain more specific information about the design in the form of program code.

The Unified Modeling Language (UML) can also be used to transmit knowledge about future application systems from one developer to another. UML is vital to some individuals because it serves as a bridge or interpreter between system developers and consumers. Here, the user can comprehend the system that will be developed in the future.

Several examples of Unified Modeling Language (UML) are as follows: (Booch et al., 1999)

1. Use Case Diagram

A use case diagram is a form of diagram in the Unified Modeling Language (UML) that depicts the interactions between actors (users or external systems) and the system itself to provide an overview of the functional requirements of a system. Use case diagrams are commonly employed in software engineering to represent and communicate the intended user behavior of a system.

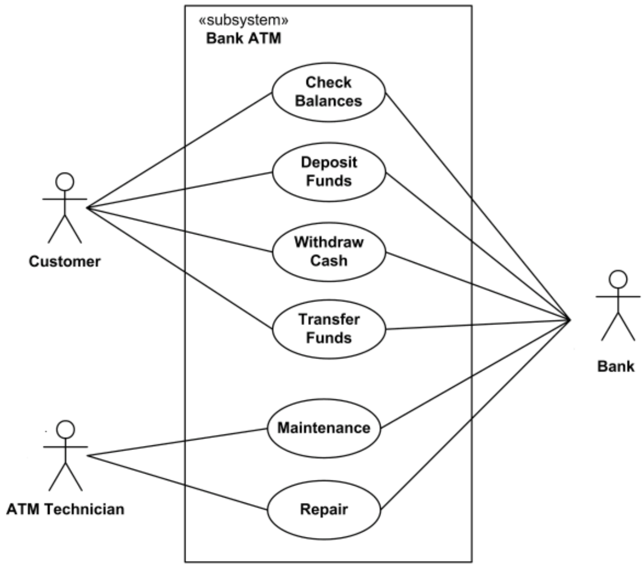

Figure 2. 15 Use Case Diagram
(Source: https://www.dicoding.com/)

Key components of a use case diagram consist of:

1. Actors
   Actors are the external entities or consumers that interact with the system. An actor could be a person, another system, or even a piece of hardware. Actors are represented as stick figures or rectangles beyond the system boundary.
2. Use Cases
   Use cases represent the specific capabilities or actions that a system offers its consumers. They characterize the interactions between actors and the system in order to accomplish a specific objective. Use cases are depicted as ovals within the system boundary and are connected to actors via associations, which are depicted as lines.
3. Relationship
   Use case diagrams can depict various forms of relationships between actors and use cases, such as:
   - Associations
     Associations are the communication connection between an actor and a use case. They demonstrate how an actor interacts with a specific use case.
   - Generalization/Inheritance
     This relationship signifies that one use case or actor inherits the characteristics and behaviors of another. It is represented by a curved projectile with an open triangle at its tip.

- Include
  This relationship indicates that one use case incorporates the functionality of another. It denotes that the included use case is an integral component of the including use case.
- Extend
  The extend relationship represents optional or alternative functionality that can be introduced to a use case under specific conditions. It demonstrates that the behavior of one-use case is extended by another use case.
- System Boundary
  The system boundary represents the purview or limit of the system being modeled. It encompasses all system use cases and actors and defines what is within the system and what is outside of it.

2. Activity Diagram

An activity diagram is a type of diagram in the Unified Modeling Language (UML) that depicts the flow of activities or business processes within a system. It depicts the sequential and concurrent actions, decisions, and conditions that occur during the execution of a particular task or workflow. Activity diagrams are commonly employed in software development, business process modeling, and system analysis to represent and document complex workflows. Key elements of an activity diagram consist of:

1. Activities
   Activities represent specific duties or actions that take place within a system. They are depicted as circular rectangles connected by arrows to show the flow of control between activities. Activities may consist of actions, decisions, iterations, and other operations.
2. Control Flow
   Arrows or edges are used to depict the flow of control from one activity to the next, signifying the execution order of the activities. The control flow arrows indicate the execution orientation by connecting the activities.
3. Decision Nodes
   Represented by diamond-shaped symbols, decision nodes represent locations in a workflow where a decision or branching occurs. Multiple outgoing arrows, each designated with a condition or a guard expression, indicate the potential paths based on the condition's evaluation.
4. Fork and Join Nodes
   Fork and join nodes are used to depict parallel or concurrent activities. Fork nodes divide the flow into multiple parallel paths, while join nodes recombine the paths into a single flow.
5. Initial and Final Nodes
   An initial node is a filled circle that represents the beginning of the activity diagram. The final nodes are depicted as a hollow circle to signify the conclusion of the workflow.
6. Object Nodes

Object nodes represent the input, output, and intermediate objects involved in the activities. They can represent information, signals, or tokens that are conveyed between activities.

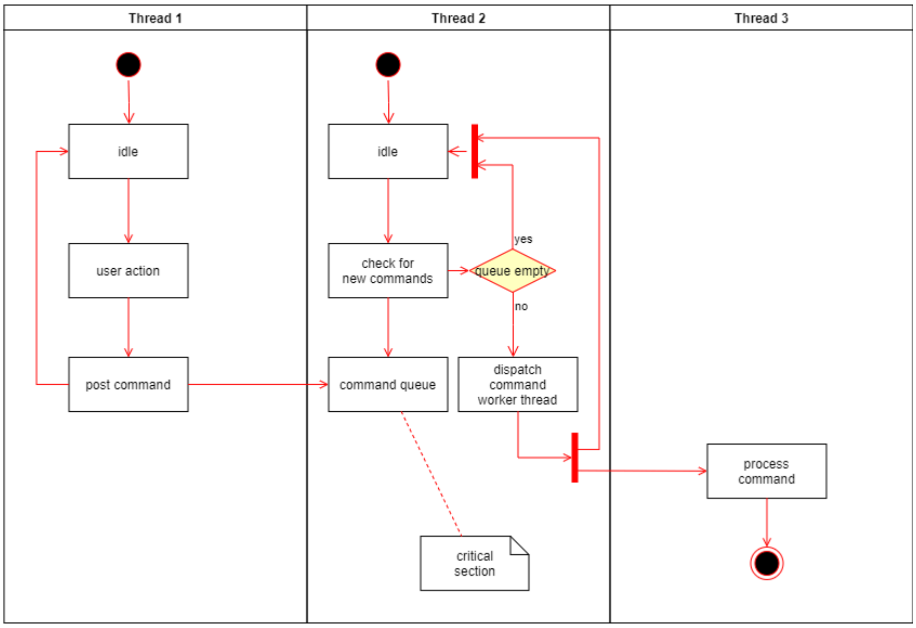

Figure 2. 16 Activity Diagram
(Source: https://www.dicoding.com/)

3. Sequence Diagram

A sequence diagram is a form of Unified Modeling Language (UML) diagram that depicts the interactions and message exchanges between objects or system components over time. It displays the chronological order of communications and the flow of control between objects and represents the dynamic behavior of a system. In software development and system design, sequence diagrams are commonly used to document and visualize the interactions between various system components. The following are essential elements of a sequence diagram:

1. Lifelines
   Lifelines represent the system's participating objects and components. They are typically depicted as vertical lines bearing the name of the object or component they represent. Lifelines depict the existence and duration of an object throughout the interaction sequence.
2. Messages
   Messages are the means of communication between lifelines. They may be synchronous or asynchronous, denoting whether the originator waits for a response or continues execution immediately. Messages are represented as arrows with labels denoting the message's name and optional parameters.
3. Activation Boxes
   Activation boxes, also known as activation bars, depict the time during which an object is actively processing a message or carrying out an operation. They are represented as spheres or rectangles on the lifeline and indicate the duration of an object's activity during a specific message exchange.

4. Return Messages
   Return messages signify the response or return value sent back to the sender from the recipient. They are represented by dashed arrows pointing back from the summoned object to the calling object.
5. Conditions and Loops
   Sequence diagrams may contain conditions and loops to depict alternative paths or repetitive behavior. Conditions are denoted by brackets or guards that specify the condition, whereas loops are indicated by an arrow pointing to the loop and a condition.
6. Combined Fragments
   In a sequence diagram, combined fragments represent complex behavior or alternative scenarios. They include loops, branches, and options, and are indicated by keywords such as "alt" (alternative), "opt" (option), "loop," and "par" (parallel).

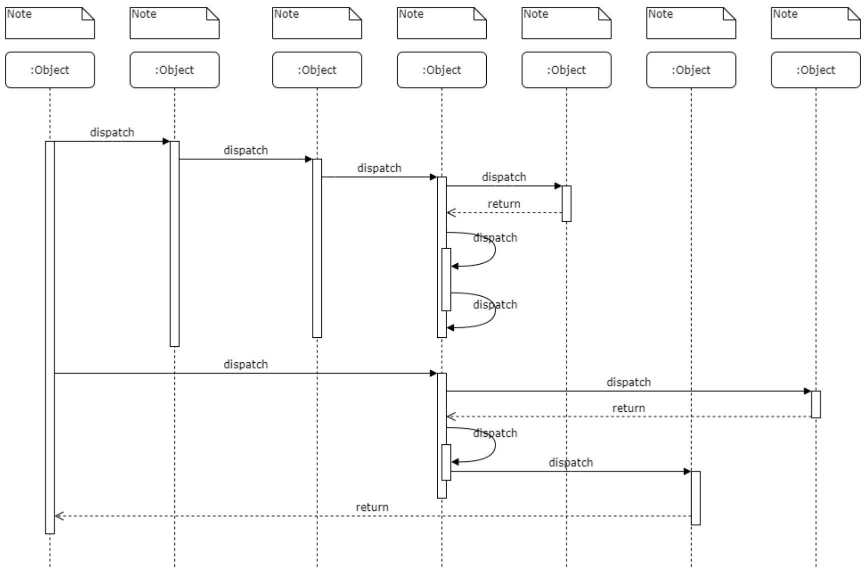

Figure 2. 17 Sequence Diagram
(Source: https://www.dicoding.com/)

2.12 Web Hosting

Web hosting is the service of storing and providing access to websites and web applications on internet-connected servers. When developing a website, we must host it on a server and make it accessible to visitors. Web hosting companies specialize in providing the infrastructure, resources, and technical support required for making website accessible online and fully functional. Web hosting operates as follows: (Domantas, 2023)

1. Server Infrastructure
   Web hosting providers maintain powerful servers situated in data centers as part of their server infrastructure. These servers are linked to high-speed Internet connections and are equipped with robust hardware and software configurations to manage website data and traffic.
2. Storage Space
   Web hosting services allocate space on their servers for the storage of website files, databases, and other resources. This storage space is typically measured in disk space, and the quantity provided is determined by the selected hosting plan.

3. Domain Name
   To access the website, we must have a domain name (e.g., www.example.com). Domain registration services are frequently provided by web hosting companies, allowing us to select and register a distinctive domain name for your website.
4. File Transfer
   Once website files (HTML, CSS, JavaScript, images, etc.) have been created, transmit them to the server using File Transfer Protocol (FTP) or other methods provided by your web host. This procedure transfers the files of the website to the server's storage space.
5. DNS Configuration
   After website files have been uploaded, we must configure the Domain Name System (DNS) settings to associate the domain name to the server hosting the website. This ensures that when users input your domain into their web browsers, they are directed to the appropriate server.
6. Website Accessibility
   Once the domain name has been configured properly, the website becomes accessible to visitors worldwide. Users can access the website by entering the domain name in their web browsers, and the hosting server delivers the website's files to the user's browser, allowing them to view and interact with the site.

Figure 2. 18 Web Hosting Working Principle
(Source: https://www.hostinger.com/)

2.13 Web-Based Application Program

A web-based application is any program that is accessed over a network connection using HTTP, rather than existing within a device's memory. Web-based applications often run inside a web browser. However, web-based applications also may be client-based, where a small part of the program is downloaded to a user's desktop, but processing is done over the internet on an external server. (Ary et al., 2018)

In other words, web-based application, also known as web apps, are software programs accessed through web browsers, eliminating the need for traditional installations. These applications utilize web technologies such as HTML, CSS, and JavaScript to deliver interactive and dynamic content. Unlike native applications, web apps do not require specific operating systems and can run on any device with a compatible browser. Several advantages of Web-Apps are as follows:(Suryawinata, 2019)

1. Cross-platform compatibility
   Web apps can run on different operating systems, including Windows, macOS, and Linux, as well as mobile platforms such as iOS and Android. This versatility enables a broad user base and facilitates seamless collaboration.
2. Easy accessibility
   Users can access web apps from anywhere with an internet connection, making them highly accessible compared to native applications that require installation. This accessibility is particularly advantageous for remote work, online collaboration, and reaching a global audience.
3. Cost-effectiveness
   Developing web-based applications can be more cost-effective than creating native applications for multiple platforms. Web apps follow a "write once, run anywhere" approach, reducing development and maintenance efforts.
4. Simplified updates and maintenance
   Web apps allow for centralized updates, ensuring that all users have access to the latest version without requiring manual installations. This simplifies maintenance and enables quick bug fixes and feature enhancements.

In addition to the above advantages, web apps also provide benefits to industrial companies in terms of collaboration and productivity. Web apps have transformed the way teams collaborate and work together. Cloud-based productivity suites like Google Workspace and Microsoft Office 365 enable real-time document editing, seamless file sharing, and efficient project management, fostering teamwork and productivity.

Web apps designed in this research are a form of asset management and maintenance systems in the company to conduct risk-based inspection of its piping systems.

In making an application, it takes some software/application to develop several systems in it. More specifically, some of these software will help writers in building front-end and back-end web apps themselves. To build the database system, the author uses MySQL Workbench software. In addition, a server or hosting is also needed, in this case the author will use a local-host server, namely Laragon. The technologies or programming languages involved in creating this project are HTML, CSS, JavaScript, MySQL, and PHP which will be explained in more detail in the next few sub-chapters.

2.13.1 Laragon

Laragon is a powerful and user-friendly local development environment specifically designed for web developers. It aims to streamline the process of creating and managing web applications, providing a seamless and efficient workflow.

Laragon offers a straightforward installation process, allowing developers to set up a local development environment quickly. It comes with an all-in-one installer that includes essential components such as Apache, PHP, MySQL, and additional tools like Node.js and Git. This eliminates the need to install and configure each component individually, saving valuable time and effort.

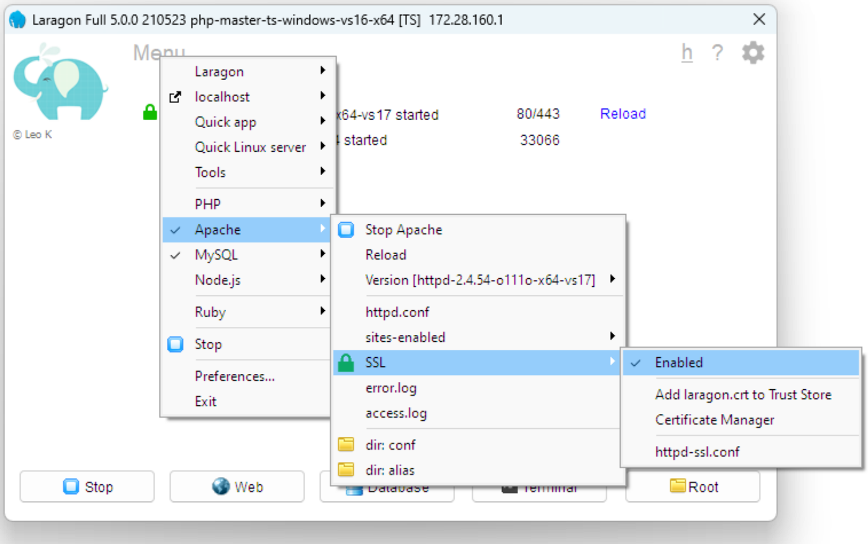

Figure 2. 19 Manage Servers in Laragon
(Source: https://php.watch/)

Several Key Features and Benefits of Laragon are as follows:

1. Easy Virtual Host Creation
Laragon simplifies the creation of virtual hosts, allowing developers to set up multiple websites effortlessly. By adding a new project folder and defining a unique domain name, Laragon automatically sets up the necessary configurations, making the project accessible via a user-defined URL.
2. Quick Switching between PHP Versions
Laragon enables developers to switch between different PHP versions with just a few clicks. This feature is particularly useful when working on projects that require specific PHP versions or when testing compatibility with different environments.
3. Integrated Database Management
Laragon provides a built-in database management tool called HeidiSQL, allowing developers to interact with databases directly from the interface. This seamless integration makes it easy to create, modify, and manage databases without the need for external tools.
4. SSL/TLS Support
Laragon supports the generation and installation of SSL/TLS certificates, enabling developers to work on secure websites locally. This feature is essential for testing and debugging applications that require HTTPS protocols or for replicating production environments accurately.
5. One-click WordPress Installation
Laragon includes a one-click installer for popular content management systems (CMS) like WordPress. With a single click, developers can set up a fully functional

WordPress installation, complete with the necessary configurations and database setup, significantly reducing the time spent on initial CMS installation and configuration.

6. Command Line Interface (CLI) Integration
   Laragon seamlessly integrates with the command line, providing developers with easy access to powerful tools and utilities. This enables advanced users to leverage the full potential of the CLI and execute various commands without leaving the Laragon environment.

2.13.2 MySQL Workbench

MySQL Workbench is a powerful and feature-rich visual tool designed for database administrators, developers, and designers working with the MySQL database management system. This comprehensive tool provides a unified environment for database development, modeling, administration, and querying.

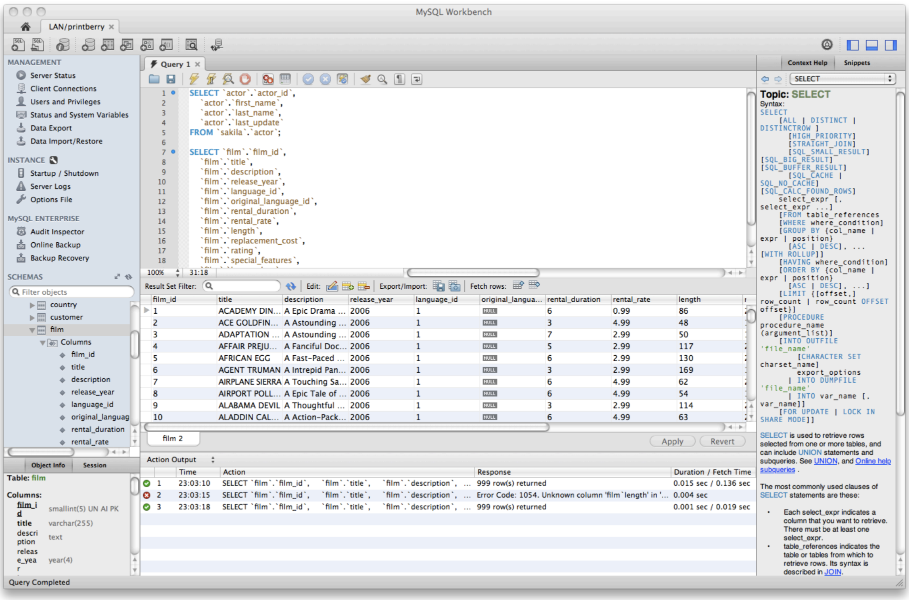

Figure 2. 20 MySQL Workbench
(Source: https://www.mysql.com/)

The key features and benefits of MySQL Workbench and how it simplifies database management tasks are as follows:

1. Database Design and Modeling
   One of the standout features of MySQL Workbench is its robust database design and modeling capabilities. It allows users to create and modify database schemas using an intuitive graphical interface. Developers and designers can define tables, relationships, and constraints visually, enabling them to efficiently design and optimize complex database structures. The tool supports both logical and physical data modeling, facilitating collaboration and documentation throughout the development process.
2. SQL Development and Querying
   MySQL Workbench offers a built-in SQL editor that provides a convenient environment for writing and executing SQL queries. The editor features syntax highlighting, code completion, and error checking, helping developers write accurate

SQL statements. The tool also supports stored procedures, triggers, and functions, allowing users to create and modify database logic directly within the interface. With the query execution capabilities, users can run and analyze SQL queries and view the results in a tabular format.

3. Database Administration
   MySQL Workbench simplifies database administration tasks by providing a wide range of tools and functionalities. Administrators can easily manage user accounts, set privileges, and monitor database performance using the graphical interface. The tool offers features such as backup and restore, import and export, and server configuration, ensuring efficient and secure management of the MySQL database environment. Additionally, it provides a visual representation of server status and performance metrics, aiding in monitoring and optimization.
4. Data Migration
   MySQL Workbench facilitates smooth data migration between different database systems. It supports seamless migration from Microsoft SQL Server, Microsoft Access, PostgreSQL, and other database platforms to MySQL. The tool provides a step-by-step wizard that guides users through the migration process, allowing them to map tables, convert data types, and transfer data accurately. This feature simplifies the transition to MySQL, ensuring minimal disruption and data loss during database migration.
5. Collaboration and Documentation
   MySQL Workbench promotes collaboration among team members by providing features for version control integration, enabling users to track and manage changes to the database schema and objects. Additionally, the tool offers extensive documentation capabilities, allowing users to generate detailed reports, diagrams, and data dictionaries. These features help maintain a comprehensive record of the database structure, improving documentation and knowledge sharing.

2.13.3 Visual Studio Code

Visual Studio Code (VS Code) is a widely adopted code editor developed by Microsoft. With its extensive range of features and flexibility, it has gained popularity among developers across various programming languages and platforms.

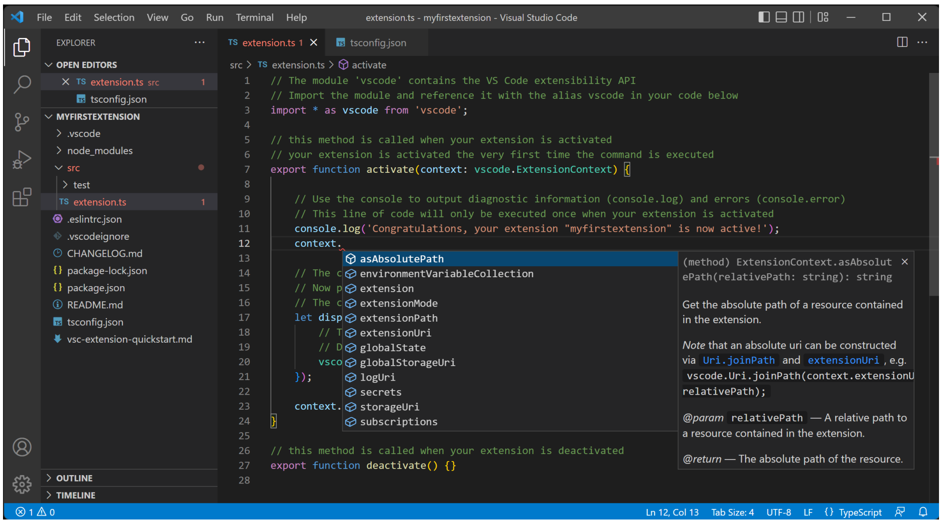

Figure 2. 21 Visual Studio Code
(Source: https://code.visualstudio.com/)

The key aspects and benefits of Visual Studio Code, highlighting its versatility, productivity-enhancing tools, and ecosystem are as follows:

1. Feature-Rich Editing Environment
   Visual Studio Code provides a feature-rich editing environment that caters to the needs of developers. Its intuitive user interface and customizable layout allow users to tailor their coding environment to suit their preferences. The editor supports a wide range of programming languages with features like syntax highlighting, autocompletion, and code snippets, providing a seamless coding experience.
2. Extensibility and Ecosystem
   One of the standout features of Visual Studio Code is its extensibility. With a vast library of extensions, developers can enhance the editor's capabilities and adapt it to their specific workflow. These extensions offer functionalities such as linting, debugging, version control integration, and language support. The active community continually contributes new extensions, ensuring a thriving ecosystem that meets the evolving needs of developers.
3. Integrated Version Control
   Visual Studio Code seamlessly integrates with popular version control systems like Git, making it easy for developers to manage and track code changes. The built-in source control features provide a visual representation of code differences, allowing users to stage, commit, and push changes directly from the editor. This integration streamlines the development process and promotes efficient collaboration within teams.
4. Integrated Terminal and Debugging
   VS Code includes an integrated terminal, enabling developers to execute commands and run scripts without leaving the editor. This tight integration eliminates the need to switch between multiple applications, enhancing productivity and workflow efficiency. Furthermore, the editor offers robust debugging capabilities, allowing users to set breakpoints, inspect variables, and step through code, facilitating the identification and resolution of issues.

5. Intelligent Code Completion and Suggestions
   Visual Studio Code leverages machine learning and intelligent algorithms to provide powerful code completion and suggestions. It analyzes code context, syntax, and the installed extensions to offer relevant recommendations and completions as developers write code. This intelligent assistance speeds up development, reduces errors, and improves code quality.
6. Cross-Platform Support
   Visual Studio Code supports multiple operating systems, including Windows, macOS, and Linux, making it accessible to a broad range of developers. Its consistent interface and functionality across platforms ensure a seamless development experience regardless of the operating system being used. This cross-platform support promotes collaboration and allows developers to work on their preferred devices.

2.13.4 HTML

HTML (Hypertext Markup Language) is a standard language used to create web pages. It defines the structure and content of a webpage using tags. (Muthohir, 2021)

Tags are enclosed in angle brackets (<>) and consist of an opening tag and a closing tag. Elements like headings, paragraphs, images, links, and more are created using these tags. HTML allows us to format and organize content on a webpage. It is the foundation of the World Wide Web and provides the structure that web browsers use to display content. By using HTML, we can create the basic structure and layout of a webpage, making it an essential language for web development.

2.13.5 CSS

CSS (Cascading Style Sheets) is a styling language used to enhance the appearance of HTML documents. It allows us to control the layout, colors, fonts, and other visual aspects of web pages. With CSS, we can select HTML elements and apply various styles to them. These styles are defined using CSS rules, which consist of a selector and one or more declarations. The selector specifies which HTML elements to target, and the declarations define the styles to be applied. (Muthohir, 2021)

CSS also offers selectors that allow you to target elements based on their class, ID, attributes, and more. This gives us fine-grained control over which elements to style. Additionally, CSS provides the concept of cascading, allowing you to apply multiple styles to an element and specify the order of precedence. By separating the presentation (styling) from the content (HTML structure), CSS promotes consistency, reusability, and ease of maintenance. It enables web designers and developers to create visually appealing and responsive web pages that adapt to different devices and screen sizes.

2.13.6 JavaScript

JavaScript is a popular programming language used to make web pages interactive and dynamic. It enables you to add functionality, respond to user actions, manipulate and validate data, and create engaging user experiences. With JavaScript, we can perform a wide range of tasks on web pages. We can dynamically update content, such as displaying the current time or updating information without reloading the entire page. JavaScript can also handle user interactions, such as capturing button clicks, form submissions, and keyboard events, allowing you to respond to user input in real-time. (Muthohir, 2021)

The language provides powerful features like variables, functions, and conditional statements, which allow us to store and manipulate data, control program flow, and make decisions. JavaScript also supports object-oriented programming, allowing you to create reusable and modular code by defining classes and objects.

In addition to manipulating HTML elements and interacting with users, JavaScript can communicate with web servers using APIs (Application Programming Interfaces). This allows us to fetch and send data asynchronously, making it possible to build interactive web applications and connect with external services.

JavaScript is supported by all modern web browsers, making it a versatile and widely-used language for web development. It can be embedded directly within HTML documents using <script> tags or stored in external JavaScript files and linked to HTML pages. Many frameworks and libraries have been developed around JavaScript, such as React, Angular, and Vue.js, which provide additional tools and abstractions to simplify web development and enhance productivity.

2.13.7 MySQL

MySQL is a popular open-source relational database management system (RDBMS) that is widely used for managing and organizing data. It provides a robust and scalable platform for storing, retrieving, and manipulating structured data. MySQL stores data in tables, which consist of rows and columns. Tables can be related to each other through keys and relationships, allowing for efficient retrieval and manipulation of data. It supports various data types, including integers, strings, dates, and more, to accommodate different types of information. (Solichin, 2005)

MySQL offers a powerful query language called SQL (Structured Query Language) for interacting with the database. SQL allows you to perform operations like creating and modifying tables, inserting, updating, and deleting data, and executing complex queries to retrieve specific information. One of the key strengths of MySQL is its performance and scalability. It is designed to handle large volumes of data and can efficiently execute queries even in high-demand environments. MySQL also provides features like indexing, caching, and optimization techniques to improve query performance.

Additionally, MySQL provides features for data backup, replication, and clustering, allowing for high availability and data redundancy. It can be used for a wide range of applications, from small-scale web applications to enterprise-level systems. MySQL is widely adopted and has a large and active community of developers and users. It is continuously updated and improved, ensuring compatibility with modern technologies and industry standards.

2.13.8 PHP

PHP (Hypertext Preprocessor) is a widely-used server-side scripting language designed for web development. It is an open-source language that is embedded within HTML code and executed on the server before being sent to the client's browser. PHP offers a range of features that make it a popular choice for web development. It is versatile and can be used to build various types of websites, from simple personal blogs to complex e-commerce platforms. PHP is easy to learn and has a large community of developers, providing extensive documentation, tutorials, and resources. (Solichin, 2005)

One of the main advantages of PHP is its ability to generate dynamic web pages. It can interact with databases, handle form submissions, process data, and generate dynamic content based on user input or other conditions. PHP supports a wide range of databases, including MySQL, PostgreSQL, and Oracle, allowing seamless integration with database systems. PHP also offers a vast collection of built-in functions and libraries, making it easier to perform common tasks such as string manipulation, file handling, and working with arrays.

Additionally, PHP can be extended with various frameworks and libraries, such as Laravel, Symfony, and WordPress, which provide pre-built components and tools to speed up development and enhance functionality. Another benefit of PHP is its platform independence. It can run on different operating systems (such as Windows, Linux, macOS) and is compatible with most web servers (such as Apache, Nginx). This makes it highly accessible and adaptable to various hosting environments. PHP has strong support for server-side scripting, session management, and security features. It allows you to create user authentication systems, handle cookies and sessions, and protect against common web vulnerabilities. With PHP, you can build secure and interactive web applications.

CHAPTER 3 RESEARCH METHODOLOGY

In this chapter will describe and describe the research methodology of this bachelor thesis. Research methodology is a systematic and comprehensive approach that guides author in conducting precise and credible investigations. It involves a series of well-defined steps and selecting an appropriate research design that corresponds with the study's objectives. Relevant data is gathered through surveys, interviews, experiments, and observations, among other methods, based on the research design. The collected data is then analyzed using quantitative or qualitative methods, and the results are interpreted in order to draw meaningful conclusions.

Ethical considerations play a crucial role throughout the research process, ensuring the preservation of participants' rights and the validity of the study. In the end, research methodology enables author to produce reliable and valid findings, contributing to the advancement of knowledge and addressing crucial concerns in a variety of academic disciplines.

In result, this chapter of research methodology is the backbone of any scientific investigation, providing author with a road map to explore the unknown and draw informed conclusions. It highlights the importance of a well-designed study, data integrity, and ethical conduct, nurturing academic and professional communities' trust in research findings. Author can generate knowledge that paves the way for future advances and enhancements in society if they keep to thorough research methodology.

3.1 Research Flowchart

In this study, there are two core works carried out in general, namely risk-based inspection assessment and the creation and development of web-based applications. Of the two-core works, there are several steps that are also carried out.

In risk-based inspection assessment, it is necessary to collect data and asset information and corrosion loop and inventory group analysis before calculating probability of failure (POF) and consequence of failure (COF). After calculating the probability and consequence of failure, the assessment continues on risk analysis and inspection planning.

After performing a series of RBI assessment steps, application modeling can begin. This modeling aims to illustrate how the application will later work. Modeling will also greatly facilitate the next step, namely application programming. At this stage of application programming, various technologies are needed to build both the front-end and back-end of the application itself. To run the application according to the initial plan, application testing is required. At the testing stage, it can be known whether there are still errors or not from the application being developed. The flow of this research methodology can be seen in Figure 3.1.

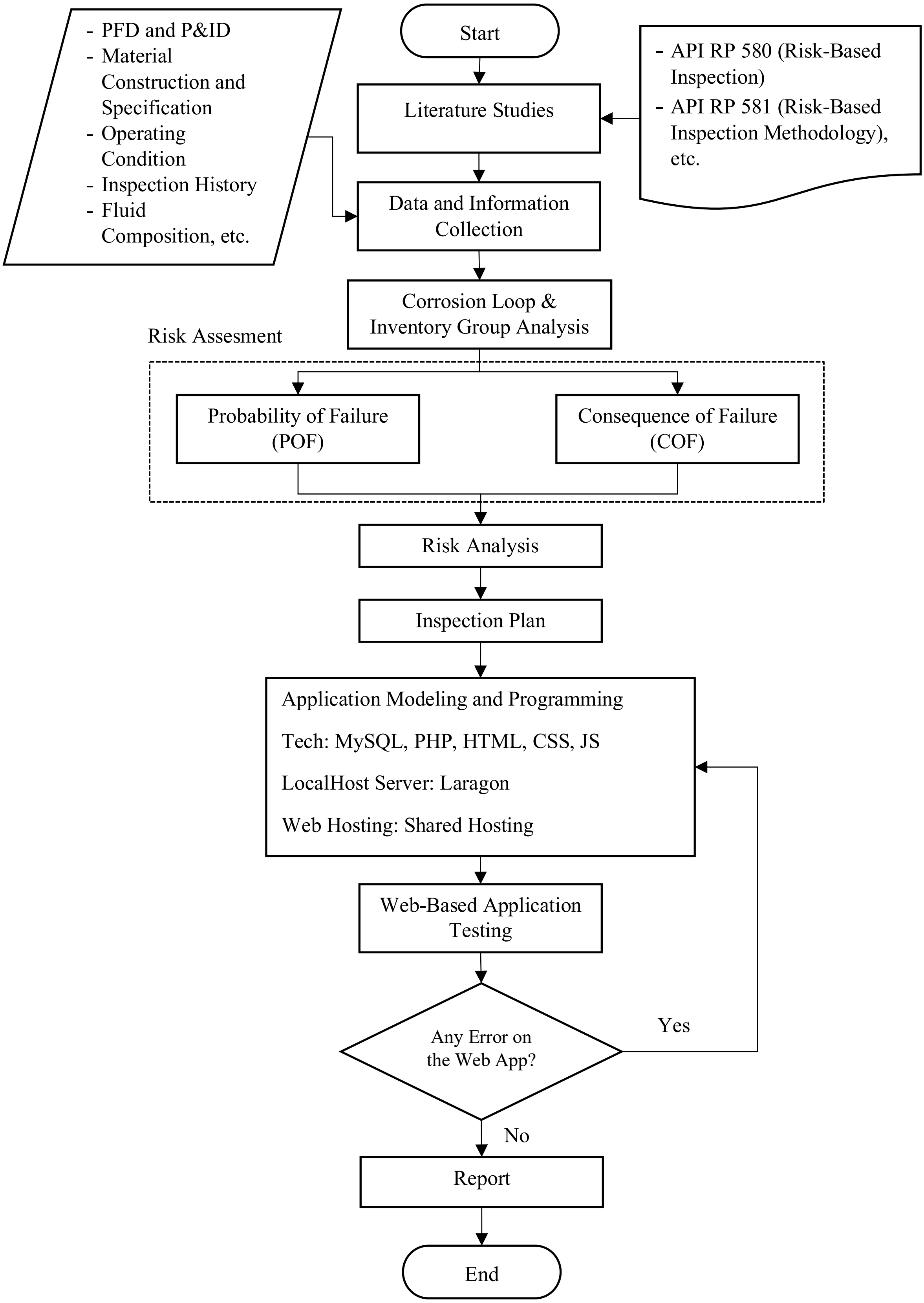

Figure 3. 1 Research Flowchart

3.2 Literature Studies

Literature studies are carried out with the aim of summarizing basic theories, references in general and specifically, as well as to obtain various other supporting information related to the work of this research. Literature studies are carried out by reading and summarizing the contents of books / guidelines / standards, theses or journals related to the final project, and by conducting discussions with supervisors. For the Literature used in this study is:

1. API RP 580 (Risk-Based Inspection)
2. API RP 581 (Risk-Based Inspection Methodology)
3. API RP 571 (Damage Mechanisms Affecting Fixed Equipment in the Refining Industry)
4. API 570 Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems
5. Asset Integrity Management Handbook by Dr. Peter McClean Millar
6. Piping and Pipeline Engineering by George A. Antaki, P.E.
7. Company Database
8. Related Reliable Books and Journals

3.3 Data and Information Collection

The data collection method is carried out by collecting data on the construction and operation of the gas piping system in CPF managed by PT X. Data needed include PFD, P &ID, the composition of the processed fluid, the design and operation of the gas piping system, inspection history, and other supporting data.

The data obtained will then be used in the identification of damage mechanisms, calculation of probability of failure, calculation of consequence of failure, analysis of risk levels, planning inspection strategies, and scheduling inspection programs.

3.4 Corrosion Loop and Inventory Group Analysis

A corrosion loop is a specific area or system within a facility where corrosion is likely to occur. It is a term used to identify and assess the risk associated with corrosion in a particular section of equipment or piping. Corrosion loops are typically identified based on factors such as the type of fluid flowing through the system, the temperature, the presence of impurities or corrosive substances, and other environmental conditions. These factors can contribute to the corrosion process and increase the likelihood of degradation or failure of the equipment. This corrosion loop will be very useful in determining the damage mechanism that occurs in equipment, usually one corrosion loop group has the same damage mechanism.

While inventory group is a collection or grouping of several equipment located between two safety or shutdown valves. The way to determine the inventory group is to estimate if there is a leak in one of the equipment, then which equipment fluid will be affected by the leak. Determination of the barrier by two sthutdown valves is needed as part of one of the activities when the leak occurs.

3.5 Probability of Failure (POF)

The method for calculating the Probability of Failure (POF) for piping is covered in API RP 581 Part 2. POF is based on the types of components and damage mechanisms that exist such as the characteristics of the fluid being served, design conditions, construction materials, and its basic construction code.

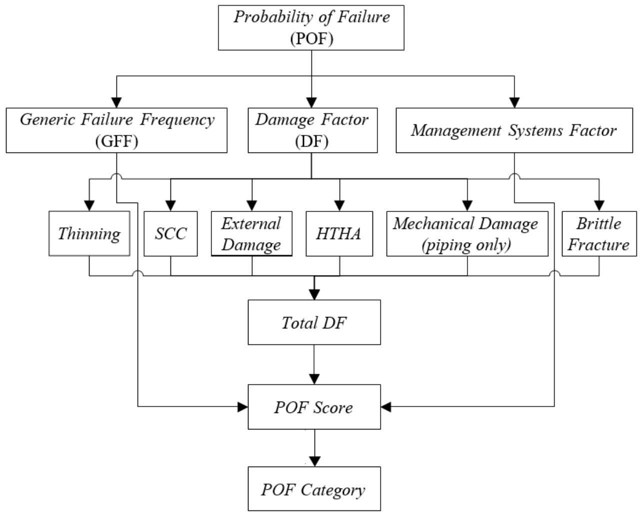

Figure 3. 2 Probability of Failure Methodology

POF is as a function of timing and inspection effectiveness is determined by using generic failure frequencies, factor management systems, and DF for active damage mechanisms. For the calculation of POF can be formulated mathematically as **Equation 3.1**.

$$\text{Pf}\,(t) = \text{gfftotal. Df}\,(t).\,FMS \tag{3.1}$$

Where Pf (t) is the probability of failure determined by gfftotal (generic failure frequency), Df (t) as the damage factor (DF), and management system factor FMS.

3.5.1 Generic Failure Frequency

The GFF is intended to be the failure frequency representative of failures due to degradation from relatively benign service prior to accounting for any specific operating environment and is provided for several discrete hole sizes for various types of processing equipment as provided in Table 3.1. The overall GFF for each component type was divided across the relevant hole sizes, i.e., the sum of the generic failure frequency for each hole size is equal to the total generic failure frequency for the component.

3.5.2 Damage Factor

DF is determined based on the applicable damage mechanisms relevant to the materials of construction and the process service, the physical condition of the component, and the inspection techniques used to quantify damage. In API RP 581, there are 21 types of damage factors as follows:

1. Thinning Damage Factor
2. Component Lining Damage Factor
3. SCC Damage Factor – Caustic Cracking
4. SCC Damage Factor – Amine Cracking

5. SCC Damage Factor – Sulfide Stress Cracking
6. SCC Damage Factor – HIC / SOHIC – H2S
7. SCC Damage Factor – Alkaline Carbonate Cracking
8. SCC Damage Factor – PTA Cracking
9. SCC Damage Factor – CLSCC
10. SCC Damage Factor – HSC-HF
11. SCC Damage Factor – HIC / SOHIC – HF
12. External Corrosion Damage Factor – Ferritic Component
13. External CLSCC Damage Factor Austenitic Component
14. CUI Damage Factor – Ferritic Component
15. External CUI CLSCC Damage Factor – Austenitic Component
16. HTHA Damage Factor
17. Brittle Damage Factor
18. Temper Embrittlement Damage Factor
19. Embrittlement Damage Factor
20. Sigma Phase Embrittlement Damage Factor
21. Piping Mechanical Fatigue Damage Factor

All of those damage factors have their own criteria. To start calculating the probability of failure in certain components, a damage factor screening is carried out in order to find out what kind of damage occurs in these components. The screening can be done through component data and on-site observations.

Thinning is a type of damage factor that is commonly found in piping systems, including gas piping systems in some company facilities. Carbon acid or atmospheric corrosion is this area's most common cause of thinning. As a result, the following step will explain the thinning damage factor and how to calculate it.

Table 3. 1 Suggested Component Generic Failure Frequencies (Source: API RP 581, 2016)

Equipment Type	Component Type	gff as a Function of Hole Size (failures/yr)				gff_{total} (failures/yr)
		Small	Medium	Large	Rupture	
Compressor	COMPC	8.00E-06	2.00E-05	2.00E-06	0	3.00E-05
Compressor	COMPR	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
Heat Exchanger	HEXSS. HEXTS,	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
Pipe	PIPE-1, PIPE-2	2.80E-05	0	0	2.60E-06	3.06E-05
Pipe	PIPE-4, PIPE-6	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
Pipe	PIPE-8, PIPE-10, PIPE-12, PIPE-16, PIPEGT16	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
Pump	PUMP2S, PUMPR, PUMP1S	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
Tank650	TANKBOTTOM	7.20E-04	0	0	2.00E-06	7.20E-04
Tank650	COURSE-1-10	7.00E-05	2.50E-05	5.00E-06	1.00E-07	1.00E-04
Vessel/FinFan	KODRUM, COLBTM, FINFAN, FILTER, DRUM, REACTOR, COLTOP, COLMID	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
Note: See references [1] through [8] for discussion of failure frequencies for equipment						

3.5.3 Thinning Damage Factor

The following are some principles of thinning damage factor that must be known before calculating the value of thinng damage factor (DFthin) itself.

1. The Df calculation for components subject to damage mechanisms that cause general or local thinning
2. All components should be checked for thinning
3. In the thinning Df calculation, it is assumed that the thinning corrosion rate is constant over time
4. For this reason, using long term average corrosion rate is recommended for the use of Df calculation
5. Thinning type should be assigned as localized wall loss or general and uniform
6. If multiple thinning mechanisms are possible and both general and localized thinning mechanism, the localized thinning type should be used

3.5.4 Thinning Damage Factor Methodology

To calculate the damage factor value of the damage mechanism thinning, there are several stages that must be taken. In its stages, some parameters that need to be determined are nominal thickness, age of equipment, corrosion rate, inspection thickness reading, time in service since last inspection, minimum requirement thickness of the component, Art parameter, flow stress, strength ratio parameter, inspection effectiveness factor, posterior probabilities, and other parameters as can be seen in the **Figure 3.3**.

3.5.5 External Corrosion Damage Factor

In general, plants located in areas with high annual precipitation or milder marine locations are more susceptible to external corrosion than plants located in cooler, drier, midcontinental locations. Units located near cooling towers and steam vents, regardless of climate, are highly susceptible to external corrosion, as are units whose operational temperatures frequently cycle through the dew point. Through appropriate painting, external corrosion can be mitigated. A regular program of paint inspection and repainting will prevent the majority of instances of external corrosion.

3.5.6 External Corrosion Damage Factor Methodology

To calculate the damage factor value of the external corrosion, there are several stages that must be taken. In its stages, some parameters that need to be determined are the base and final corrosion rate, in-service time over which external corrosion may have occured, the allowable stress, weld joint efficiency, and minimum required thickness, Art parameter, flow stress, strength ratio parameter, inspection effectiveness factor, posterior probabilities, and other parameters as can be seen in the **Figure 3.4**.

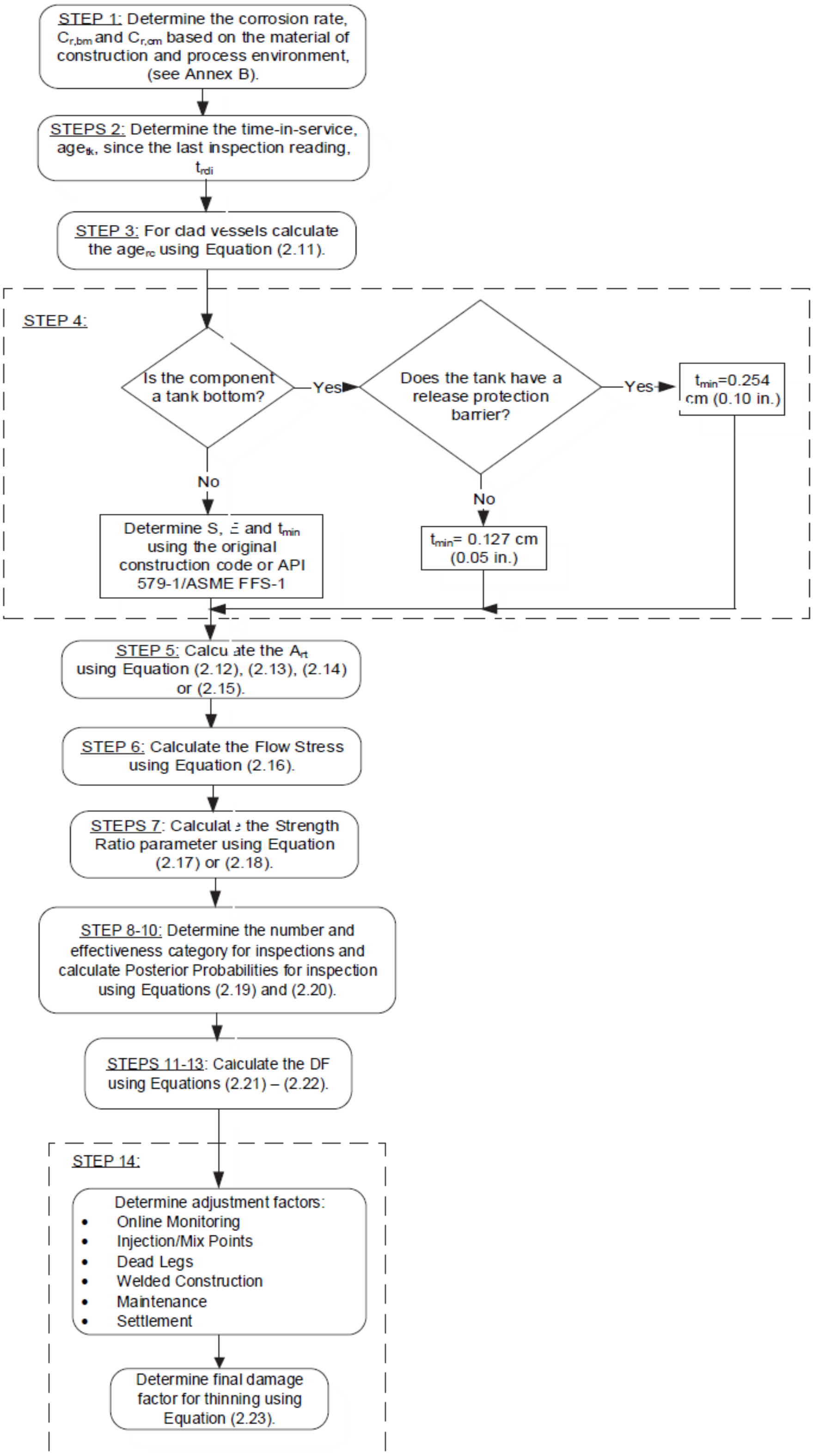

Figure 3. 3 Thinning Damage Factor Methodology (Source: API RP 581, 2016)

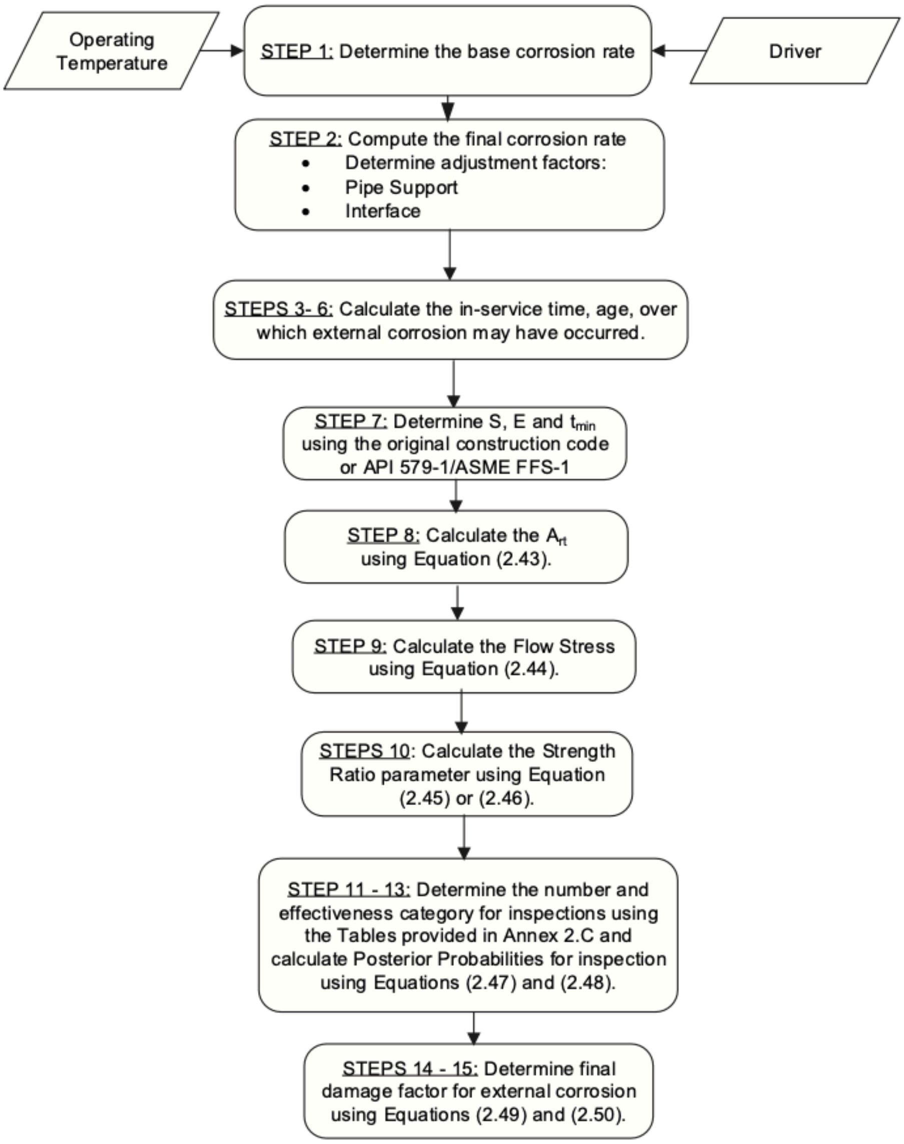

Figure 3. 4 External Corrosin Damage Factor Methodology
(Source: API RP 581, 2016)

3.5.7 Management System Factor

Managenement system factor is a factor of the influence of system management on the mechanical integrity of components. This factor is influenced by the probability of damage accumulated over a long time and is proportional to the quality of the integrity of the mechanical program of a facility.

To determine the value of pscore, an evaluation of the company's management system should be carried out. Table 3.3 contains a list of the subjects covered in the management systems evaluation as well as the weight assigned to each subject. After getting the evaluation score, it must first be converted to a percentage (between 0 and 100) as follows.

Table 3. 2 Management Systems Evaluation
(Source: API RP 581, 2016)

Table	Title	Questions	Points
2.A.1	Leadership and Administration	6	70
2.A.2	Process Safety Information	10	80
2.A.3	Process Hazard Analysis	9	100
2.A.4	Management of Change	6	80
2.A.5	Operating Procedures	7	80
2.A.6	Safe Work Practices	7	85
2.A.7	Training	8	100
2.A.8	Mechanical Integrity	20	120
2.A.9	Pre-Startup Safety Review	5	60
2.A.10	Emergency Response	6	65
2.A.11	Incident Investigation	9	75
2.A.12	Contractors	5	45
2.A.13	Audits	4	40
Total		**101**	**1,000**
Note: Tables 2.A.1 through 2.A.13 are located in Annex 2.A.			

3.6 Consequence of Failure (COF)

The methodology for calculating the Consequence of Failure (COF) of the piping system is covered in API RP 581 Part 3. The COF methodology is carried out to establish the risk level of equipment items based on risk and is also intended to be used to set priorities for inspection programs. The COF methodology will be used to assist in assigning equipment ratings based on risk and is also intended to set priorities for inspection programs. According to API RP 581, there are two types of COF levels, Level 1 and Level 2, which have different fluid characteristic applications from each other. The COF Level 1 methodology is used for the specified list of hazardous liquids. The Level 2 COF methodology is intended to be more rigorous and can be applied to a broader range.

3.6.1 Consequence Categories

The major consequence categories are analyzed using different techniques.

a. Flammable and the explosive consequence is calculated using event trees to determine the probabilities of various outcomes (e.g., pool fires, flash fires, vapor cloud explosions), combined with computer modeling to determine the magnitude of the consequence. Consequence areas can be determined based on serious personnel injuries and component damage from thermal radiation and explosions. Financial losses are determined based on the area affected by the release.
b. Toxic consequence is calculated using computer modeling to determine the magnitude of the consequence area as a result of overexposure of personnel to toxic concentrations within a vapor cloud. Where fluids are flammable and toxic, the toxic event probability assumes that if the release is ignited, the toxic consequence is negligible (i.e., toxics are consumed in the fire). Financial losses are determined based on the area affected by the release.
c. Non-flammable, non-toxic releases are considered since they can still have serious consequences. The consequence of chemical splashes and high-temperature steam

burns are determined based on serious injuries to personnel. Physical explosions and Boiling Liquid Expanding Vapor Explosions (BLEVE) can also cause serious personnel injuries and component damage.

d. Financial consequence includes losses due to business interruption and costs associated with environmental releases. Business interruption consequence is estimated as a function of the flammable and non-flammable consequence area results. The environmental consequence is determined directly from the mass available for release or from the release rate.

Table 3. 3 Representative Fluids Properties in Level 1 Consequence Analysis (Source: API RP 581, 2016)

Fluid	MW	Liquid Density (lb/ft^3)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	C_p Ideal Gas Constant *A*	Ideal Gas Constant *B*	Ideal Gas Constant *C*	Ideal Gas Constant *D*	Ideal Gas Constant *E*	Auto-Ignition Temp. (°F)
C1-C2	23	15.639	-193	Gas	Note 1	12.3	1.150E-01	-2.87E-05	-1.30E-09	N/A	1036
C3-C4	51	33.61	-6.3	Gas	Note 1	2.632	0.3188	-1.347E-04	1.466E-08	N/A	696
C5	72	39.03	97	Liquid	Note 1	-3.626	0.4873	-2.6E-04	5.3E-08	N/A	544
C6-C8	100	42.702	210	Liquid	Note 1	-5.146	6.762E-01	-3.65E-04	7.658E-08	N/A	433
C9-C12	149	45.823	364	Liquid	Note 1	-8.5	1.01E+00	-5.56E-04	1.180E-07	N/A	406
C13-C16	205	47.728	502	Liquid	Note 1	-11.7	1.39E+00	-7.72E-04	1.670E-07	N/A	396
C17-C25	280	48.383	651	Liquid	Note 1	-22.4	1.94E+00	-1.12E-03	-2.53E-07	N/A	396
C25+	422	56.187	981	Liquid	Note 1	-22.4	1.94E+00	-1.12E-03	-2.53E-07	N/A	396
Water	18	62.3	212	Liquid	Note 3	2.76E+05	-2.09E+03	8.125	-1.41E-02	9.37E-06	N/A
Steam	18	62.3	212	Gas	Note 3	3.34E+04	2.68E+04	2.61e+03	8.90E+03	1.17E+03	N/A
Acid	18	62.3	212	Liquid	Note 3	2.76E+05	-2.09E+03	8.125	-1.41E-02	9.37E-06	N/A
H_2	2	4.433	-423	Gas	Note 1	27.1	9.270E-03	-1.38E-05	7.650E-09	N/A	752
H_2S	34	61.993	-75	Gas	Note 1	31.9	1.440E-03	2.430E-05	-1.18E-08	N/A	500
HF	20	60.37	68	Gas	Note 1	29.1	6.610E-04	-2.03E-06	2.500E-09	N/A	32000

Notes:

1. $C_p = A + BT + CT^2 + DT^3$ with T in K, units for C_p are J/kmol-K
2. $C_p = A + B\left(\frac{\frac{C}{T}}{\sinh\left[\frac{C}{T}\right]}\right)^2 + D\left(\frac{\frac{E}{T}}{\cosh\left[\frac{E}{T}\right]}\right)^2$ with T in K, units for C_p are J/kmol-K
3. $C_p = A + BT + CT^2 + DT^3 + ET^4$ with T in K, units for C_p are J/kmol-K
4. Pyrophoric materials, by definition, auto-ignite and therefore, a very low value for the AIT is assumed.
5. Conversion factor for units of C_p is 1 J/kmol-K = 5.27×10^{-4} Btu/kmol-°R

3.6.2 Consequence of Failure Level 1 Methodology

To calculate the consequence are based on level 1 methodology, there are several stages that must be taken. In its stages, some parameters that need to be determined are phase of fluid, operating temperature and pressure, release hole size, release rate, fluid inventory available for release, maximum mass available for release, release type, the release rate and mass, and other parameters as can be seen in the **Figure 3.5**.

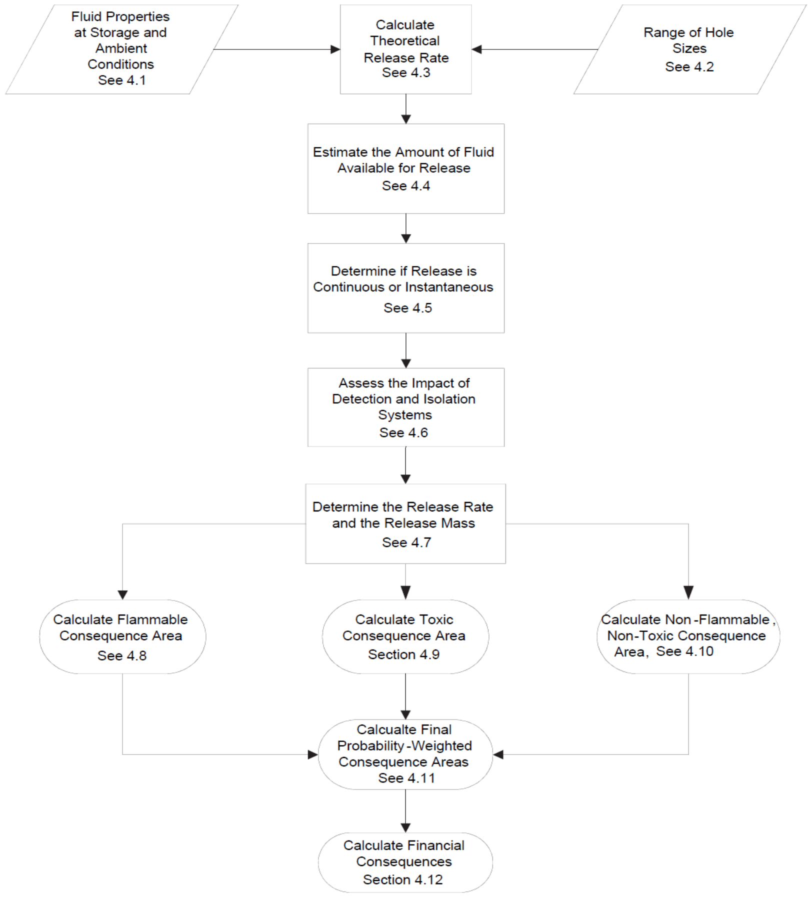

Figure 3. 5 Consequence of Failure Level 1 Methodology (Source: API RP 581, 2016)

3.7 Risk Ranking

Risk is defined as a combination of the probability of an event over a period of time and its consequences (generally negative) of the associated event. A system consists of several or many components, each of which has its own risks. Of course, because these components are part of the system, failures in the components can have an impact on the system both in terms of performance and age. Then the probability of component risk must be maintained at an acceptable level by conducting testing or inspection.

Mathematically, risk can be defined as the **Equation 3.2**.

$$Risk = Pf(t) . Cf(t) \quad (3.2)$$

Where Pf(t) is the probability of failure, Cf(t) is the consequence of its failure. From the equation, it can be concluded that an effective risk assessment must be rational, logical, structured and contain how significant the impact of the risk is, whether the risk is acceptable and how high the probability of the risk occurs.

After calculating the Probability of Failure (POF) and Consequence of Failure (COF), the result of the risk level is known. Furthermore, inspection planning is carried out using appropriate treatment methodologies in accordance with the results of known risk levels. If the results are received, it can continue to carry out inspection planning using the appropriate treatment methodology. On the other hand, if the result is rejected, then, we must perform some mitigation measures that require to recalculate the POF and COF until the result is fully accepted.

The risk matrix is a way to determine the level of risk of the components. Red indicates a high risk, orange indicates a medium-high level of risk, yellow indicates that the risk of failure of the component is at a medium level, green indicates the risk at a low level. An example of a risk matrix image is shown in **Figure 3.6**.

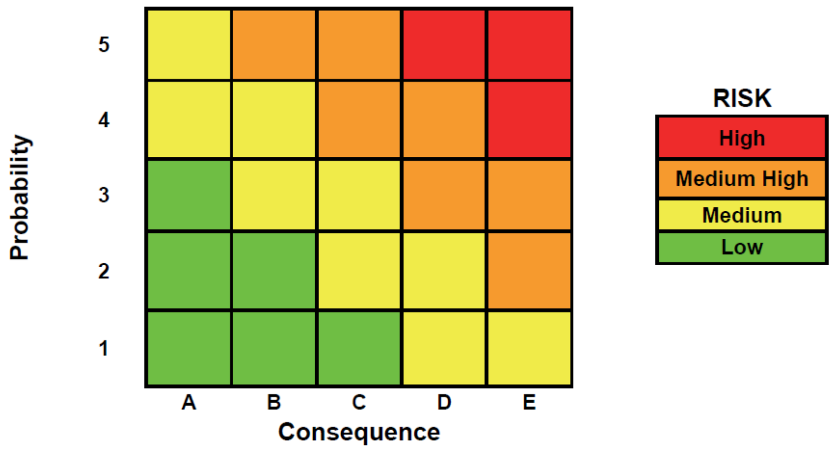

Figure 3. 6 Risk Matrix
(Source: API RP 581, 2016)

In Figure 3.3, the horizontal axis is the level of consequence of failure, and the vertical axis is the level of probability of failure or damage factor. For classification of values can be seen in Table 3.16.

Table 3. 4 Numerical Values Associated with POF and Area-Based COF Categories
(Source: API RP581, 2016)

Category	Probability Category (1,2)		Consequence Category (3)	
	Probability Range	Damage Factor Range	Category	Range (ft^2)
1	$P_f(t, I_E) \le 3.06E-05$	$D_{f-total} \le 1$	A	$CA \le 100$
2	$3.06E-05 < P_f(t, I_E) \le 3.06E-04$	$1 < D_{f-total} \le 10$	B	$100 < CA \le 1,000$
3	$3.06E-04 < P_f(t, I_E) \le 3.06E-03$	$10 < D_{f-total} \le 100$	C	$1,000 < CA \le 10,000$
4	$3.06E-03 < P_f(t, I_E) \le 3.06E-02$	$100 < D_{f-total} \le 1,000$	D	$10,000 < CA \le 100,000$
5	$P_f(t, I_E) > 3.06E-02$	$D_{f-total} > 1,000$	E	$CA > 100,000$

Notes:
1. POF values are based on a GFF of 3.06E-05 and an F_{MS} of 1.0.

3.8 Inspection Planning

After the risk level is known, proceed to make an inspection strategy according to the risk level. If the results are acceptable, we can continue to carry out the inspection plan using the appropriate maintenance methodology. On the other hand, if the results are rejected, then we have to do some mitigation steps, which require recalculating POF and COF until the results are fully accepted.

Inspections are designed based on the risk level of equipment according to the risk analysis using RBI. Equipment with a higher level of risk will be prioritized for inspection. Inspections are carried out when the risk or condition of the equipment has exceeded the target set by the company. The targets that can be set with the RBI for mitigation actions are:

- Risk Target – minimum risk level for conducting inspection planning. It can be either area units (m2/year) or financial ($/year).
- Target POF – Maximum limit of acceptable failure/leakage frequency (#/year) or can trigger inspection planning.
- Target DF – The maximum damage value (factor of PoF) that is acceptable or can trigger an inspection plan.
- Target COF – Unacceptable level of consequence area (CA) or financial consequence (FA).
- Target Thickness – The minimum acceptable thickness can trigger an inspection plan.
- Target Interval – The maximum interval for when an inspection will be carried out.

API RP 581 does not provide specific guidelines in determining targets and must be determined based on the owner's decision. There are three internal, on-stream, and external inspections for self-inspection activities.

Internal inspection is an inspection that must be carried out when the tool is not operating. In comparison, the onstream inspection is carried out when the equipment is operating. External inspection is carried out using only visuals to check whether the structural or external conditions of the equipment are in good condition.

Inspections are carried out to reduce the risk of the equipment and obtain the latest information regarding the condition of the equipment (implementation of inspections will only reduce the probability of failure, while to reduce consequences, the design must be reviewed). The accuracy of the inspection method is called inspection effectiveness. Each damage factor has its inspection effectiveness, which is explained in API RP 581 3rd Edition – Annex 2. C. The following is an effective inspection for thinning and external corrosion.

Table 3. 5 Inspection for General Thinning
(Source: API RP 581, 2016)

Inspection Category	Inspection Effectiveness Category	Intrusive Inspection Example[1,2,3,4]	Non-intrusive Inspection Example[1,2,3,4]
A	Highly Effective	For the total surface area: >50% visual examination (partial internals removed), **AND** >50% of the spot ultrasonic thickness measurements	For the total surface area: 100% UT/RT of CML's **OR** For selected areas: 10% UT scanning, **OR** 10% profile radiography.
B	Usually Effective	For the total surface area: >25% visual examination **AND** >25% of the spot ultrasonic thickness measurements	For the total surface area: >75% spot UT **OR** >5% UT scanning, automated or manual **OR** >5% profile radiography of the selected area(s)
C	Fairly Effective	For the total surface area: >5% visual examination **AND** >5% of the spot ultrasonic thickness measurements	For the total surface area: >50% spot UT or random UT scans (automated or manual) **OR** random profile radiography of the selected area(s)
D	Poorly Effective	For the total surface area: <5% visual examination without thickness measurements	For the total surface area: >25% spot UT
E	Ineffective	Ineffective inspection technique/plan was utilized	Ineffective inspection technique/plan was utilized

Note:
1. Inspection quality is high.
2. Inspection points (CML's, scans, etc.) are set up by knowledgeable individuals
3. That the number of CML's and area for scanning (UT or profile radiography) is one that will detect damage if occurring.
4. Percentage refers to percent of established CML's examined (e.g., for spot UT) or the percent surface area examined.

Table 3. 6 Inspection for External Corrosion
(Source: API RP 581, 2016)

Inspection Category	Inspection Effectiveness Category	Inspection[1]
A	Highly Effective	Visual inspection of >95% of the exposed surface area with follow-up by UT, RT or pit gauge as required.
B	Usually Effective	Visual inspection of >60% of the exposed surface area with follow-up by UT, RT or pit gauge as required.
C	Fairly Effective	Visual inspection of >30% of the exposed surface area with follow-up by UT, RT or pit gauge as required.
D	Poorly Effective	Visual inspection of >5% of the exposed surface area with follow-up by UT, RT or pit gauge as required.
E	Ineffective	Ineffective inspection technique/plan was utilized

Note:
1. Inspection quality is high.

3.9 Application Modeling and Programming

Appication modeling and programming are two interrelated aspects of software development that are involved in the design and implementation of software applications.

Application modeling is the creation of a conceptual model or representation of a software application. It involves analyzing and comprehending the application's requirements, functionality, and structure prior to the development phase. Application modeling serves to visualize and plan the architecture, components, and behavior of a software application. Key application modeling activities include:

1. Requirement Analysis
   Gathering and analyzing the software application's functional and non-functional requirements constitutes requirement analysis. This involves comprehending the requirements of the stakeholders and delineating the application's scope.
2. System Design
   The creation of an application's blueprint or high-level design. This involves defining the application's architecture, components, interfaces, and data structures.
3. Data modeling

Data modeling is the process of designing the database schema and specifying the relationships between application data entities. This facilitates the effective organization and management of the application's data.

4. User Interface Design
   User Interface Design is the process of designing the application's user interface and interaction flow. This requires the creation of wireframes, mockups, and prototypes to visualize how users will interface with the application.
5. Application programming, also known as software development or coding, is the implementation of a software application based on the models and designs developed during the modeling phase. It entails composing code utilizing programming languages and frameworks to create the software application. Key application programming activities include:
6. Selecting a Programming Language
   Choosing a programming language that best meets the application's needs. This decision is based on efficacy, scalability, platform compatibility, and the expertise of the development team.
7. Coding
   The process of translating application models and designs into executable code. This requires writing functions, classes, modules, and algorithms to implement the application's intended functionality.
8. Debugging and Testing
   The processes of identifying and resolving errors or bugs in the code via debugging and testing. This ensures that the application functions properly and conforms to the requirements specified.
9. Integration and Deployment
   Integrating application modules and components and deploying the application to the desired environment, such as servers, cloud platforms, or mobile devices.

Programming and application modeling are iterative processes, with feedback and refinement occurring between each stage. Effective application modeling ensures that the application is designed and implemented in a structured and efficient manner by laying a firm foundation for programming. Programming, on the other hand, transforms the models and designs into a functional, requirements-compliant software application.

3.10 Application Testing

After doing the previous step, namely application modeling and programming, the application must go through a trial process to find out whether the application is in accordance with the model or planning determined at the beginning or not. In this stage, application testing is done by moving the progrmming data from the localhost server to the web hosting first. With the connection of web hosting with a web domain, the application can be run online or connected to the internet. Failures or errors that occur in the application when running must be found a solution to be reprogramming by editing the code that has been compiled.

CHAPTER 4 RESULT AND DISCUSSION

4.1 Asset Data and Information

Completeness of data and information related to assets is needed before a risk-based inspection assessment is carried out. These data include piping design and construction, piping operational data, fluid data served by piping, inspection data and other detailed data needed in the risk-based inspection methodology at API RP 581.

These data will be processed in accordance with the calculation formula contained in API RP 581 both in the calculation of probability of failure and consequence of failure Such as data regarding the starting date of equipment, component geometry, design code, design pressure, design temperature, cladding, coating, etc. Other data related to asset data, general properties of equipment, and component data can be seen in **Appendix B**.

4.2 Corrosion Loop and Inventory Group Analysis

To determine corrosion loop, there are several data and equipment information needed. As explained in the research methodology chapter, the grouping of corrosion loops is based on the similarity of several data and parameters, such as equipment material and construction, insulation present, fluid, fluid phase, operating temperature, operating pressure, CO2 content, H2S content, H2O content, chloride, and corrosion rate. From these parameters, it can also be known the damage mechanism of each equipment. The results of the corrosion loop analysis can be seen in the P&ID and PFD in **Appendix C** and **Appendix D.**

Table 4. 1 Registered Pipe in Corrosion Loop

PIPE		
TAG NUMBER	DESCRIPTION	
	From	To
340-PG-1001-10"-06S3	Acid Gas Absorber **340-T-1001**	Sweet Gas KO Drum **340-D-1002**

Table 4. 2 Registered Vessel in Corrosion Loop

VESSEL		
TAG NUMBER	DESCRIPTION	SEG.
340-T-1001	ACID GAS ABSORBER	Top
340-D-1002	SWEET GAS KO DRUM	Middle

If corrosion loop is used to determine the damage mechanism for calculating probability of failure, it is different from the inventory group which will be used in calculating the consequence of failure as a scenario if there is a leak in an equipment. In determining the inventory group, it is necessary to imagine if there is a leak, then the fluid in which equipment will be affected. This is where the role of some shutdowns or safety valves is to limit equipment outside certain inventory groups from being affected by leaks. The results of the corrosion loop analysis can be seen in the P&ID and PFD in **Appendix C** and **Appendix D**.

Table 4. 3 Registered Pipe in Inventory Group

PIPE			
TAG NUMBER	DESCRIPTION		
	From	To	
330-C0-1007-10"-06H0 330-C0-1024-6"-06H0	Cooler KO Drum **330-D-1002 A**	Feed Gas Prophane Chiller **340-E-1008 A/B**	a. SDV
340-C0-1033-6"-06H0-C 340-C0-1005-10"-06H0-C	Feed Gas Prophane Chiller **340-E-1008 A/B**	Feed Gas KO Drum **340-D-1001**	
340-GH-1020-2"-06H0	Feed Gas KO Drum **340-D-1001**	HP Scrubber **320-D-1003**	b. SDV
340-C0-1002-10"-06H0-H	Feed Gas KO Drum **340-D-1001**	Acid Gas Absorber **340-T-1001**	
340-PG-1001-10"-06S3	Acid Gas Absorber **340-T-1001**	Sweet Gas KO Drum **340-D-1002**	
340-AM-1002-8"-06S3	Amine Pumps **340-P-1001-A/B**	Acid Gas Absorber **340-T-1001**	a. SDV
340-AM-1147-8"-06S3	Acid Gas Absorber **340-T-1001**	Acid Gas Flash Drum **340-D-1003**	
340-PG-1011-10"-06S3 340-PG-1012-2"-06S3	Sweet Gas KO Drum **340-D-1002**	Dehydration Unit **350-Y-1001**	b. SDV
340-GH-1022-2"-06S3	Sweet Gas KO Drum **340-D-1002**	Acid Gas Flash Drum **340-D-1003**	b. SDV
340-GH-1021-2"-06S3	Acid Gas Absorber **340-T-1001**	Amine Sump Drum **340-D-1006**	b. Valve

Table 4. 4 Registered Vessel in Inventory Group

VESSEL	
TAG NUMBER	DESCRIPTION
340-E-1008 A/B	FEED GAS PROPHANE CHILLER
340-D-1001	FEED GAS KO DRUM
340-T-1001	ACID GAS ABSORBER
340-D-1002	SWEET GAS KO DRUM

4.3 Inspection History Data

The inspection history plays a crucial role in Risk-Based Inspection (RBI) as it provides valuable information about the condition and performance of equipment over time. Generally, it helps in assessing the effectiveness of previous inspections, identifying trends, and making informed decisions regarding future inspection and maintenance strategies.

Inspection history enables the identification of trends in equipment degradation. By analyzing historical data, patterns of deterioration or corrosion rates can be detected. Some of the inspections that have been carried out are NDT at several points in piping equipment, visual inspection, and also ultrasonic tests (UT). The results of the inspection history can be seen in **Figure 4. 1 to Figure 4. 3**.

No.	NDT Location / Part	Pipe/PV Dia. (inch)	Require Height Access		Insulation	Damage Mechanism	Inspection Method	Insp. Reference	Remarks
			Y/N	Height (m)	Y/N				
1	E1	10	Y	(+) 23.6	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
2	P2	10	Y	(+) 23.6	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
3	E3	10	Y	(+) 23.6	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
4	P4	10	Y	(+) 21.8	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
5	P5	10	Y	(+) 15.0	N	External corrosion, Thinning	UT SPOT	THU-2332 Procedure Inspection Piping THU-2323 Ultrasonic Thickness Measurement Procedure	
6	P6	10	Y	(+) 14.8	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
7	E7	10	Y	(+) 14.3	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
8	P8	10	Y	(+) 14.3	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
9	E9	10	Y	(+) 14.3	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
10	P10	10	Y	(+) 14.3	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
11	P11	10	Y	(+) 14.3	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
12	E12	10	Y	(+) 14.3	N	External corrosion, Thinning	UT SCAN	THU-2332 Procedure Inspection Piping THU-2323 Ultrasonic Thickness Measurement Procedure	
13	P13	10	Y	(+) 11.1	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
14	E14	10	Y	(+) 10.9	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
15	P15	10	Y	(+) 10.9	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
16	E16	10	Y	(+) 10.9	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
17	P17	10	Y	(+) 9.8	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
18	E18	10	Y	(+) 9.6	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
19	P19	10	Y	(+) 9.6	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
20	E20	10	Y	(+) 9.6	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
21	P21	10	Y	(+) 5.9	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
22	E22	10	Y	(+) 5.5	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
23	P23	10	Y	(+) 5.5	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
24	E24	10	Y	(+) 5.5	N	External corrosion, Thinning	Visual	THU-2332 Procedure Inspection Piping	
25	P25	10	Y	(+) 5.5	N	External corrosion, Thinning	UT SPOT	THU-2332 Procedure Inspection Piping THU-2323 Ultrasonic Thickness Measurement Procedure	

Figure 4. 1 NDT Inpection Report
(Source: Company Data)

KONDISI	STATUS			KETERANGAN
B. IDENTIFIKASI DI LAPANGAN (*FIELD IDENTIFICATION*)	**Ya**	**Tidak**	**N/A**	
B.1 Apakah Piping label/tag tertera?	☑	☐	☐	
B.2 Apakah Label/tag terbaca dengan baik?	☑	☐	☐	
B.3 Apakah Label/tag sudah sesuai spesifikasi?	☑	☐	☐	
C. KEBOCORAN (*LEAKS*)	**Ya**	**Tidak**	**N/A**	
C.1 Apakah ada kebocoran pada proses?	☐	☑	☐	
C.2 Apakah ada kebocoran steam tracing?	☐	☑	☐	
C.3 Apakah ada kebocoran pada *valves*?	☐	☑	☐	
D. KETIDAKSESUAIAN (*MISALIGNMENT*)	**Ya**	**Tidak**	**N/A**	
D.1 Apakah terjadi *Piping Misalignment/ Restricted movement*	☐	☑	☐	
D.2 Apakah ada *Expansion Join Misalignment*	☐	☑	☐	
E. GETARAN (*VIBRATION*)	**Ya**	**Tidak**	**N/A**	
E.1 Apakah ada getaran signifikan yang diamati?	☐	☑	☐	
E.2 Apakah ada indikasi *excessive movement*?	☐	☑	☐	
E.3 Apakah ada distorsi pipa yang diamati?	☐	☑	☐	
F. *PIPE SUPPORT*	**Ya**	**Tidak**	**N/A**	
F.1 Apakah terjadi *shoes off* dari supportnya?	☐	☑	☐	
F.2 Apakah *hangers missing* atau rusak?	☐	☑	☐	
F.3 Apakah *spring hangers bottomed out*?	☐	☑	☐	
F.4 Apakah ada masalah dengan *support braces*?	☐	☑	☐	
F.5 Apakah terjadi korosi pada support?	☑	☐	☐	Fair corrosion support pipe "P5"
F.6 Apakah ada loose atau patah pada *brackets*?	☐	☑	☐	
G. KOROSI (*CORROSION*)	**Ya**	**Tidak**	**N/A**	
G.1 Apakah terjadi korosi pada *contact point*?	☐	☑	☐	
G.2 Apakah ada *coating/painting deterioration*?	☑	☐	☐	Coating deterioration area pipe "P10"
G.3 Apakah ada area dengan *scale, pitting, rust*?	☑	☐	☐	Rusty area Weld joint elbow "E12, E16, E20"
G.4 Apakah terjadi korosi pada *flange connection*?	☐	☑	☐	
G.5 Apakah ada korosi pada *bolt* di flange?	☐	☑	☐	
H. INSULATION	**Ya**	**Tidak**	**N/A**	
H.1 Apakah ada kerusakan/*penetration?*	☐	☑	☐	
H.2 Apakah jacketing atau insulation hilang?	☐	☐	☑	
H.3 Apakah terjadi *sealing deterioration?*	☐	☐	☐	
H.4 Apakah terjadi *bulging*?	☐	☑	☑	
H.5 Apakah ada *band* yang patah/hilang?	☐	☑	☐	

Figure 4. 2 Visual Examination of Piping
(Source: Company Data)

ULTRASONIC TEST REPORT PIPING

No Report	: 309-PP-UT/P-134/THU-R/2022	**Equip.**	: Olympus (UTM & UFD)
Location	:	**Model**	: 38DL Plus (UTM) & Epoch 650 (UFD)
Line No. / Tag No.	: 340-PG-1001-10-06S3	**Probe**	: D7-906 SM - 5 Mhz, D795 - 5 Mhz (UTM) & A551S - 5 Mhz (UFD)
Desc. From	: Acid Gas Absorber(340-T-1001)		
To	: Sweet gas KO Drum(340-D-1002)	**Cal. Block**	: Stepwedge & V2
P & ID. No.	: MTDF-PR-340-PID-1002, MTDF-PR-340-PID-1009	**Couplant**	: Grease, Oil & CMC
Surface Temp (°C)	: 45	**Date of Inspection**	: 24 September 2022
Material	: Pipe : Carbon steel + PWHT + NACE (MR 0175)	**Last Inspection Date**	: -
	Fitting : A234-WPB SMLS BE (NACE MR0175)	**Page**	: 1 of 1

Measurement in mm

Part No.	Mark	DiaØ (Inch)	Nom. Thk	Scanning		Point Of Measurement (Orientation)				Min. Reading	Surface Condition	Remark	Prev. Measurement		
				Min	Max	1	2	3	4				Prev. Part	Min	Max
P5	Pipe	10	15.09	-	-	14.15	14.25	14.73	15.35	14.15	Smooth		-	-	-
E12	Elbow	10	15.09	12.98	14.68	-	-	-	-	12.98	Smooth	Min at 12 O'Clock (220 mm From Weld A) & Max at 12 O'Clock (110 mm From Weld B)	-	-	-
P25	Pipe	10	15.09	-	-	14.63	14.94	15.35	14.96	14.63	Smooth		-	-	-

Figure 4. 3 Ultrasonic Test Report
(Source: Company Data)

4.4 Probability of Failure Analysis

POF is as a function of timing and inspection effectiveness is determined by using generic failure frequencies, factor management systems, and DF for active damage mechanisms. The detail of the probability of failure (POF) calculation can be seen in **Appendix E**.

Table 4. 5 Probability of Failure Analysis Result

Tag Number	GFF	DFTotal	FMS	Score	Category
340-PG-1001-10-06S3	3.06E-05	1.150	1	0,058967755	2 - Unlikely

4.4.1 Generic Failure Frequency

The GFF is intended to be the failure frequency representative of failures due to degradation from relatively benign service prior to accounting for any specific operating environment and is provided for several discrete hole sizes for various types of processing equipment.

Table 4. 6 Generic Failure Frequency

Tag Number	Type	As a Function of Hole Size (failures/yr)				gfftotal (falilures/yr)
		Small	Medium	Large	Rupture	
340-PG-1001-10-06S3	PIPE-10	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05

4.4.2 Damage Factor Selection

Damage mechanism is the cause of a piece of equipment experiencing damage or disintegrity. API 581 provides 21 types of damage mechanisms as shown in **Table E. 1**. The selection of damage mechanism types is carried out by screening the composition of the piping constituent materials, the fluid served by piping, the process environment around piping, and other conditions that also affect the damage screening mechanism.

The type of damage mechanism chosen is the highest cause of damage that most affects piping performance. The piping analyzed is composed of carbon steel ASTM A106 Gr B. The fluid served is Methane.

Judging from the conditions above, the most suitable type of damage mechanism is thinning. However, the external damage mechanism also affects the piping condition so that the type of damage mechanism is a multiple damage mechanism between thinning and external corrosion.

Table 4. 7 Selected Damage Factor

Tag Number	Selected Damage Factor
340-PG-1001-10-06S3	Thinning
	External Corrosion

4.4.3 Thinning Damage Factor

Thinning is the depletion or degradation of material that occurs in a piece of equipment. Thinning generally has two types, namely local and general thinning. Local and general thinning are distinguished based on the mechanism and cause of corrosion experienced. A description of the thinning mechanism is in API RP 581 part of Annex 2.B. In this study, thinning experienced is general thinning.

The DF Thinning value is needed as one of the parameters of the probability of failure calculation. The calculation of thinning damage factor can be seen in **Appendix E.**

Table 4. 8 Thinning Damage Factor

Tag Number	Thinning Damage Factor
340-PG-1001-10-06S3	1.059

4.4.4 External Corrosion Damage Factor

In general, plants located in areas with high annual precipitation or milder marine locations are more susceptible to external corrosion than plants located in cooler, drier, midcontinental locations. Units located near cooling towers and steam vents, regardless of climate, are highly susceptible to external corrosion, as are units whose operational temperatures frequently cycle through the dew point. Through appropriate painting, external corrosion can be mitigated. A regular program of paint inspection and repainting will prevent the majority of instances of external corrosion.

The DF External Corrosion value is needed as one of the parameters of the probability of failure calculation. The calculation of external corrosion damage factor can be seen in **Appendix E.**

Table 4. 9 External Corrosion Damage Factor

Tag Number	Ext. Corrosion Damage Factor
340-PG-1001-10-06S3	0.092

4.4.5 Management System Factor

Management system factor is a factor of the influence of system management on the mechanical integrity of components. This factor is influenced by the probability of damage accumulating over a long time and is proportional to the quality of the integrity of the mechanical program of a facility. To determine the value of management system factor, we can do an assessment by following management systems work book in part 2 - Annex 2.A API RP 581. For this calculation, the actual score of assessment is assumed between 500 and 1000 where the results of the Fms is 1.

4.5 Consequence of Failure Analysis

Consequence of Failure (COF) analysis are performed to determine the risk level of equipment items based on risk and are also intended to be used to set priorities for inspection programs. The COF calculation will be carried out to assist in rating equipment based on risk and is also intended to be used to set priorities for inspection programmes. In this COF analysis, what is analyzed is the consequence area. In determining the value of the consequence area, several calculation steps are carried out such as calculating the amount of fluid available for release, the release type, the impact of detection and isolation systems, the release rate and the release mass, flammable consequence area, toxic consequence area, non-flammable non-toxic consequence area, and the final consequence area. The detail of the COF calculation is attached in **Appendix E**. **Table 4.10** shows the results of COF calculation.

Table 4. 10 Consequence of Failure Analysis Result

Tag Number	Representative Fluid	Fluid Phase	CA Score (ft^2)	Category
340-PG-1001-10-06S3	C1-C2	Gas	1577.805	C - Moderate

4.6 Risk Analysis

After going through the process of probability analysis and consequence of failure, the next process is risk analysis. In this stage, combined the results of the probability of failure and consequence of failure analysis, in addition to obtaining a risk score in units of ft^2 or m^2 per year, the combined results of the two analyses can be visualized in a risk matrix to determine the level of risk. The risk matrix used is a type of balanced risk matrix based on API RP 581 and has four risk levels, namely low, medium, medium high, and high. The results of risk analysis can be seen in **Table 4. 11** and the results of determining the risk level in the risk matrix can be seen in **Figure 4. 4**.

Table 4. 11 Risk Analysis Result

No	Tag Number	Score (ft^2/year)	Score (m^2/year)	Risk Category
1	340-PG-1001-10-06S3	0.055	0.0055	Medium

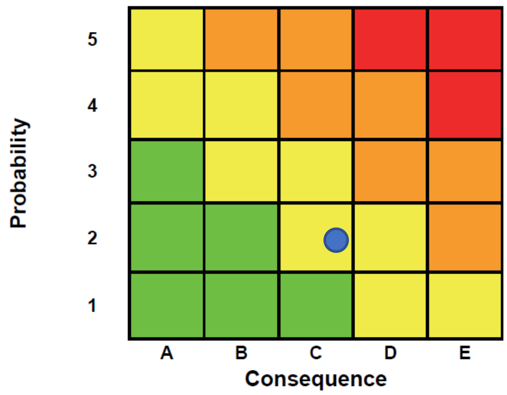

Figure 4. 4 Risk Analysis Risk Matrix Result

4.7 Inspection Planning

In the process of determining inspection planning, there are three cases or scenarios according to API 581. The three cases illustrate that inspection needs to be carried out if the risk line on the chart has intersected with the risk target line or limit. After the risk score is known in the previous risk analysis process, then what needs to be done next is to project the risk every year in the future by iterating changes in the damage factor variable. Changes in the value of damage factors, in this case damage factor thinning and external corrosion will increase the risk value every year. The risk target is set at 2 m^2/year as the limit of acceptance of the risk level by the company. The iteration table of changes in damage factor values can be seen in **Appendix E**. Based on the graph in the **Figure 4. 5**, the next inspection will be carried out on 24/03/2036.

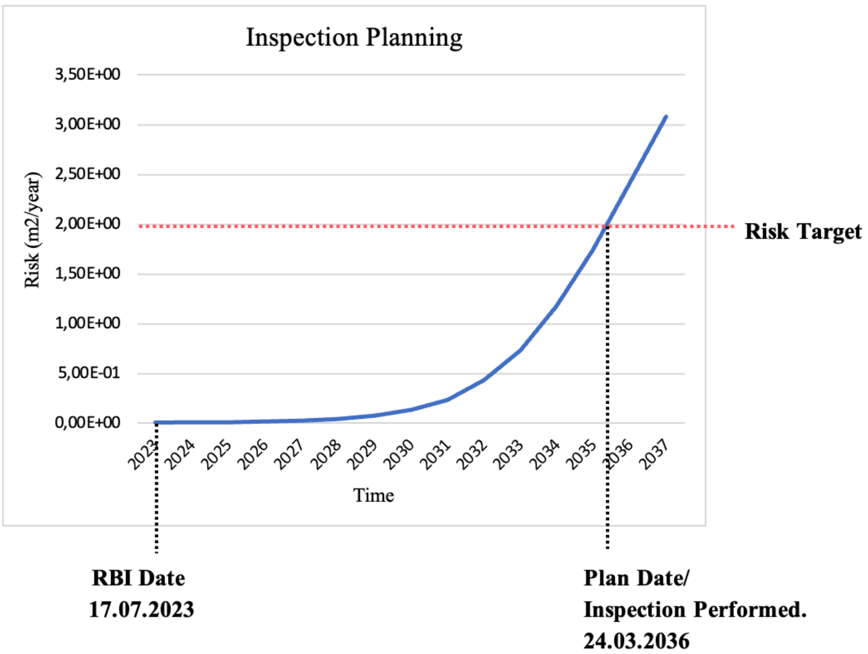

Figure 4. 5 Inspection Planning Determination Graph

Table 4. 12 Inspection Planning Schedule

Tag Number	Last Inspection	Risk Score (m^2/year)	Risk Target (m^2/year)	Plan Date
340-PG-1001-10-06S3	24/09/2022	0,0055	2	24/03/2036

In this study, the inspection effectiveness recommendation used is category C (fairly effective). The recommendation was used due to historical considerations of previous inspections. If the level of inspection is required in mitigation, then the inspection category should be upgraded to a higher level. This is useful so that mitigation can help in planning inspections ahead of time. In addition, the determination of inspection strategies according to risk levels plays a role in reducing costs and making inspection strategies more effective and strategic. The inspection recommendations can be seen in **Table 4. 13**.

Table 4. 13 Inspection Recommendations

No.	Damage Factor	Intrusive	Non-Intrusive
1	Thinning	For the total surface area: >5% visual examination AND >5% of the spot ultrasonic thickness measurements.	For the total surface area: >50% spot UT or random UT scans (automated or manual) OR random profile radiography of the selected area(s)
2	External Corrosion	Visual inspection of >30% of the exposed surface area with follow-up by UT, RT or pit gauge as required	

4.8 Application Modeling

In the application modeling stage, the author uses activity diagrams to design the work of the application system and also entity relationship diagrams (ERD) as database designs used in the application. In the activity diagram, it is divided into two activity actors, namely user and system. While in ERD, database modeling is applied in the form of what data is entered in several application menus and what type of each data is.

4.8.1 Activity Diagram

An activity diagram is a type of diagram in the Unified Modeling Language (UML) that depicts the flow of activities or business processes within a system. It depicts the sequential and concurrent actions, decisions, and conditions that occur during the execution of a particular task or workflow. Activity diagrams are commonly employed in software development, business process modeling, and system analysis to represent and document complex workflows.

In making activity diagrams in this poject, activity diagrams are created based on each menu page that will be created in this web application. The pages created are log in page, assessment page, corrosion loop & inventory group page, component data identification page, damage factor selection page, probability of failure page, consequence of failure page, risk analysis page, and inspection planning page. Activity diagrams from these pages can be seen in **Figure 4. 5** to **Figure 4. 12.**

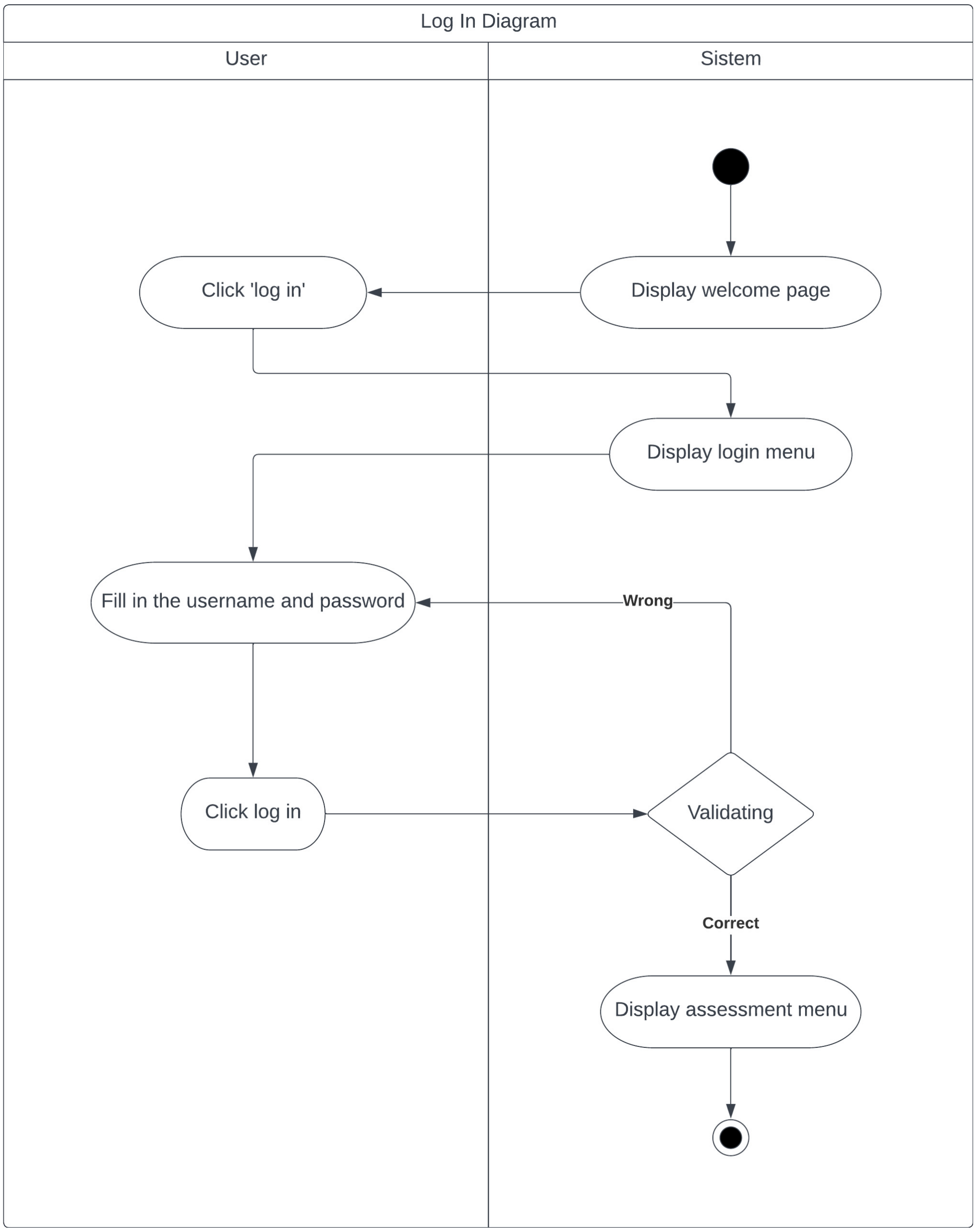

Figure 4. 6 Log In Page Diagram

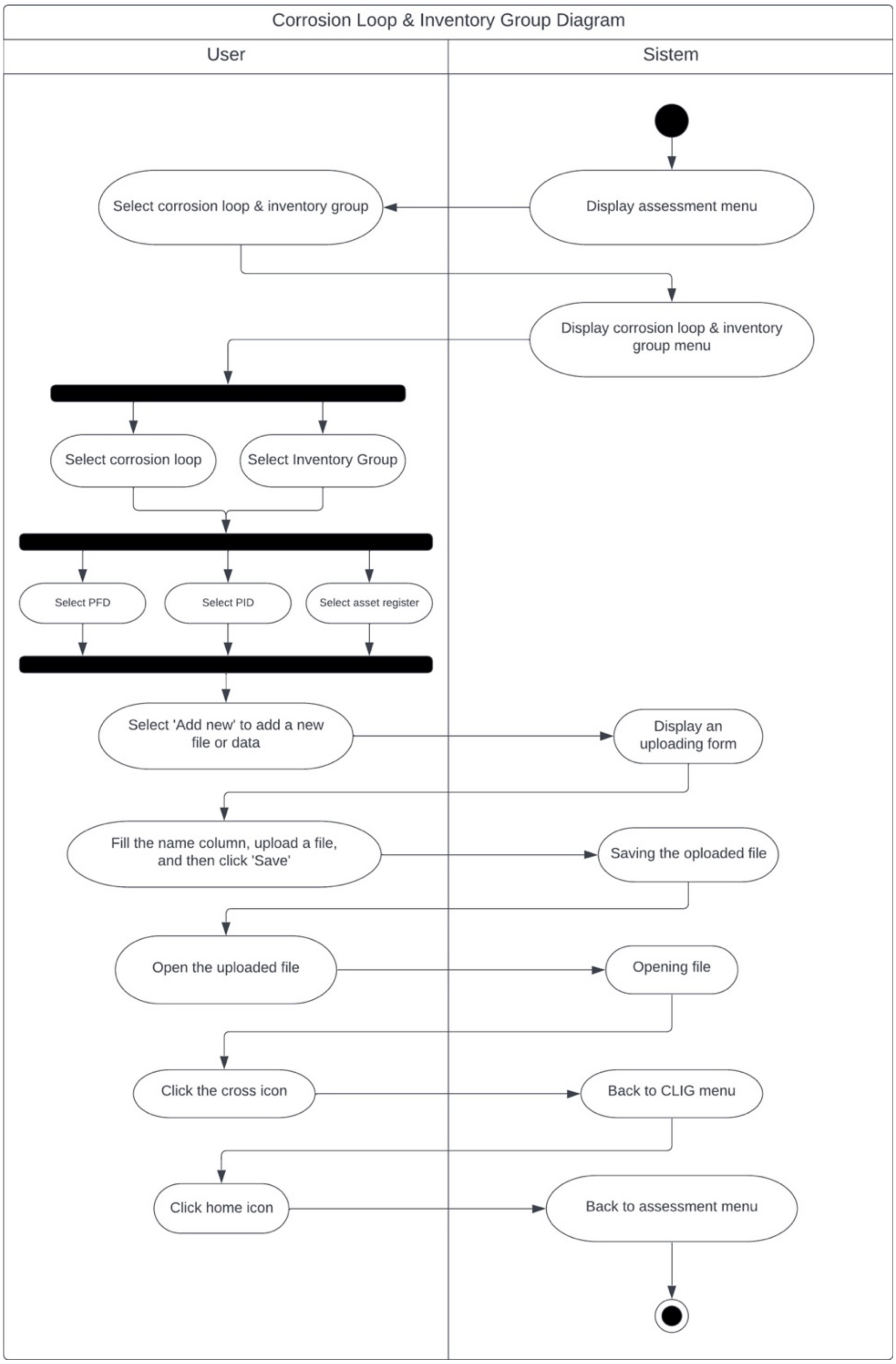

Figure 4. 7 Corrosion Loop & Inventory Group Menu Diagram

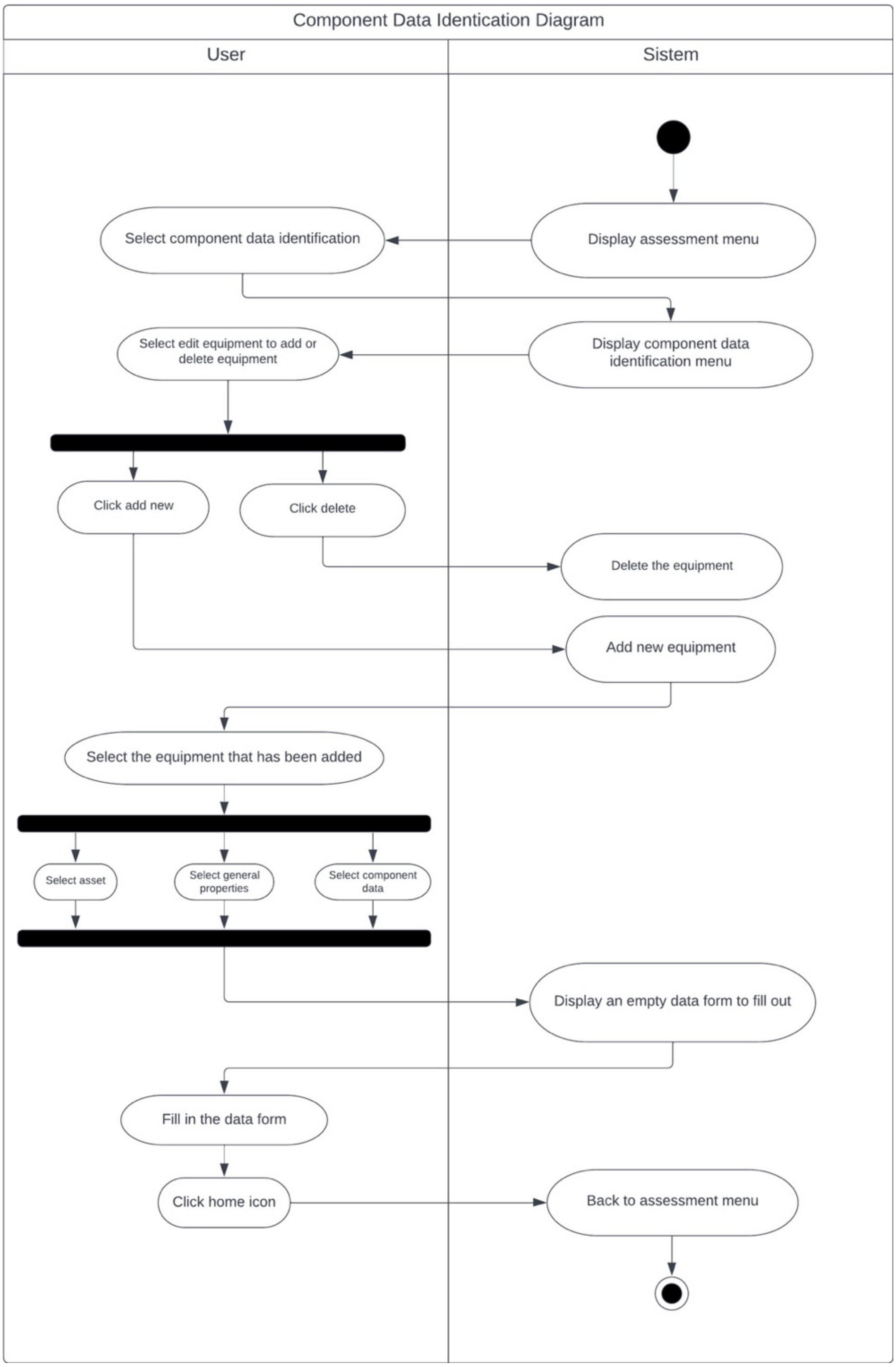

Figure 4. 8 Component Data Identification Menu Diagram

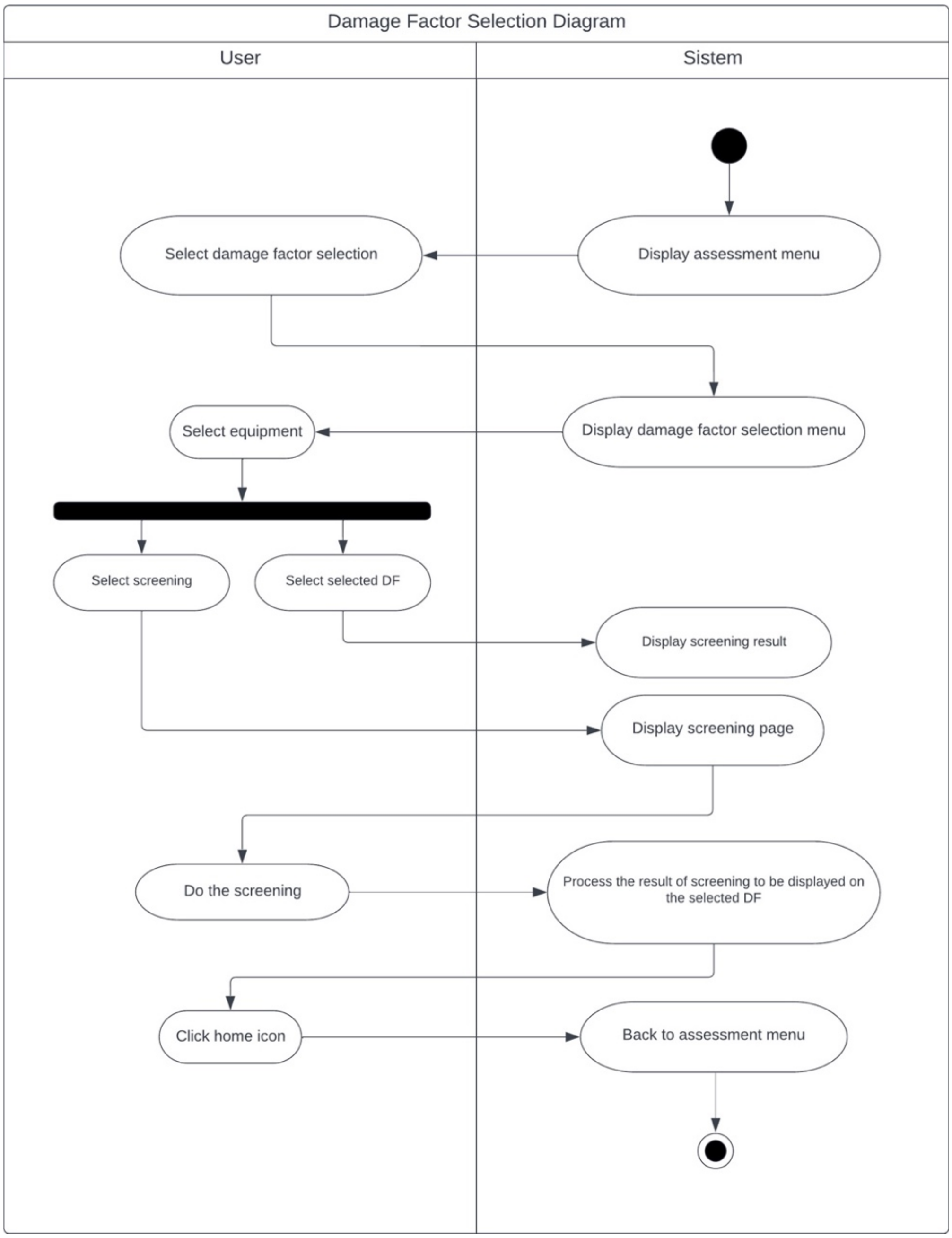

Figure 4. 9 Damage Factor Selection Diagram

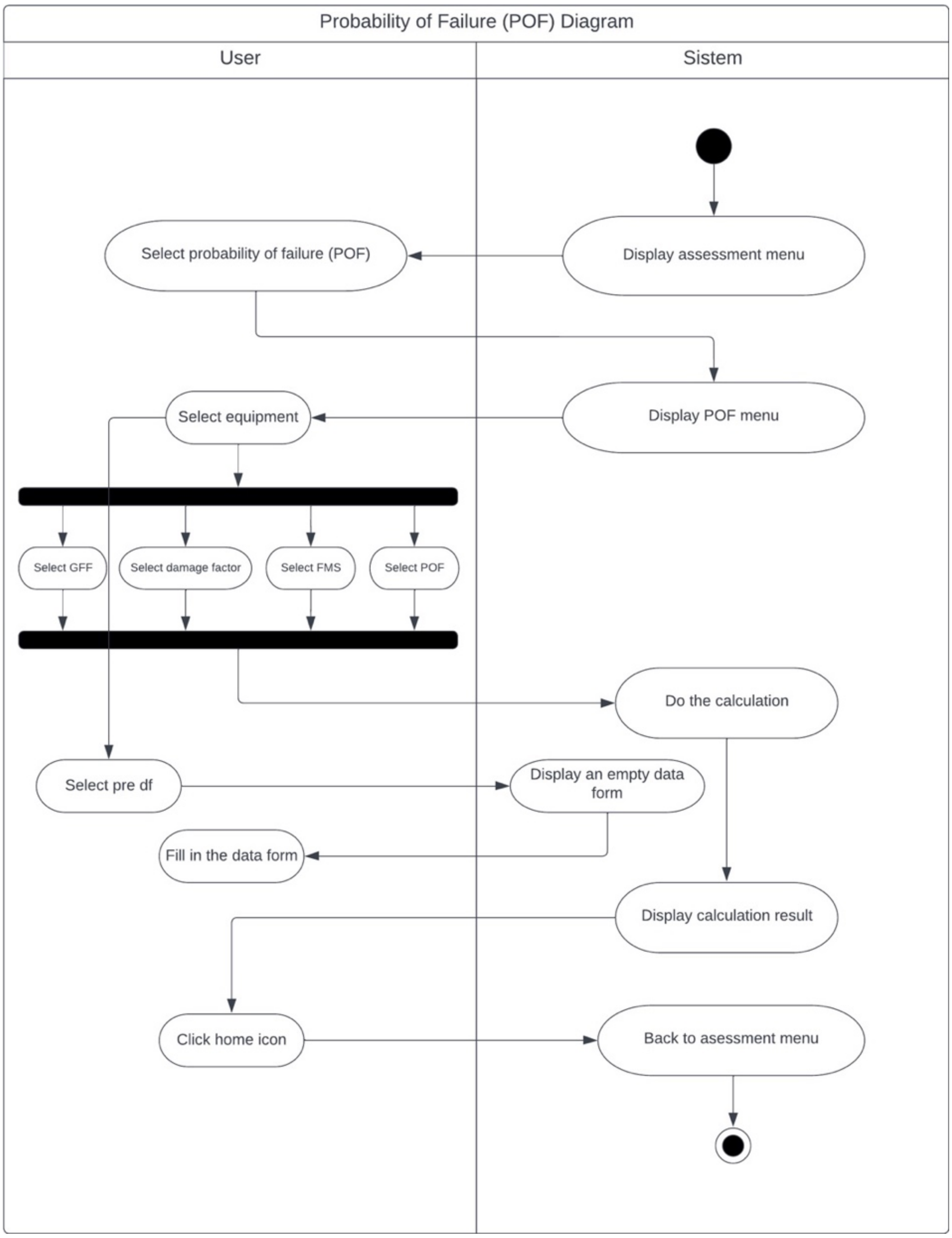

Figure 4. 10 Probability of Failure Menu Diagram

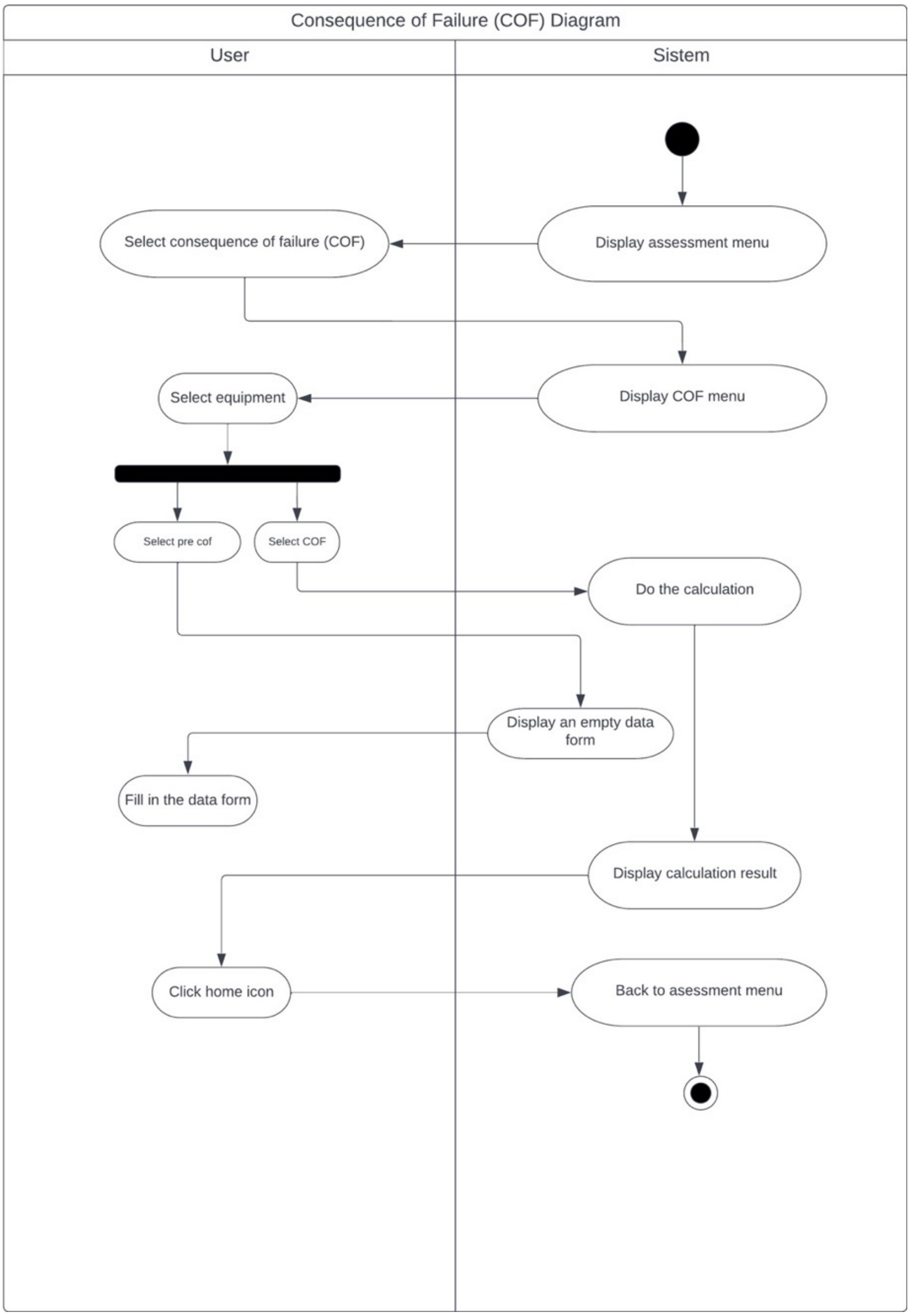

Figure 4. 11 Consequence of Failure Menu Diagram

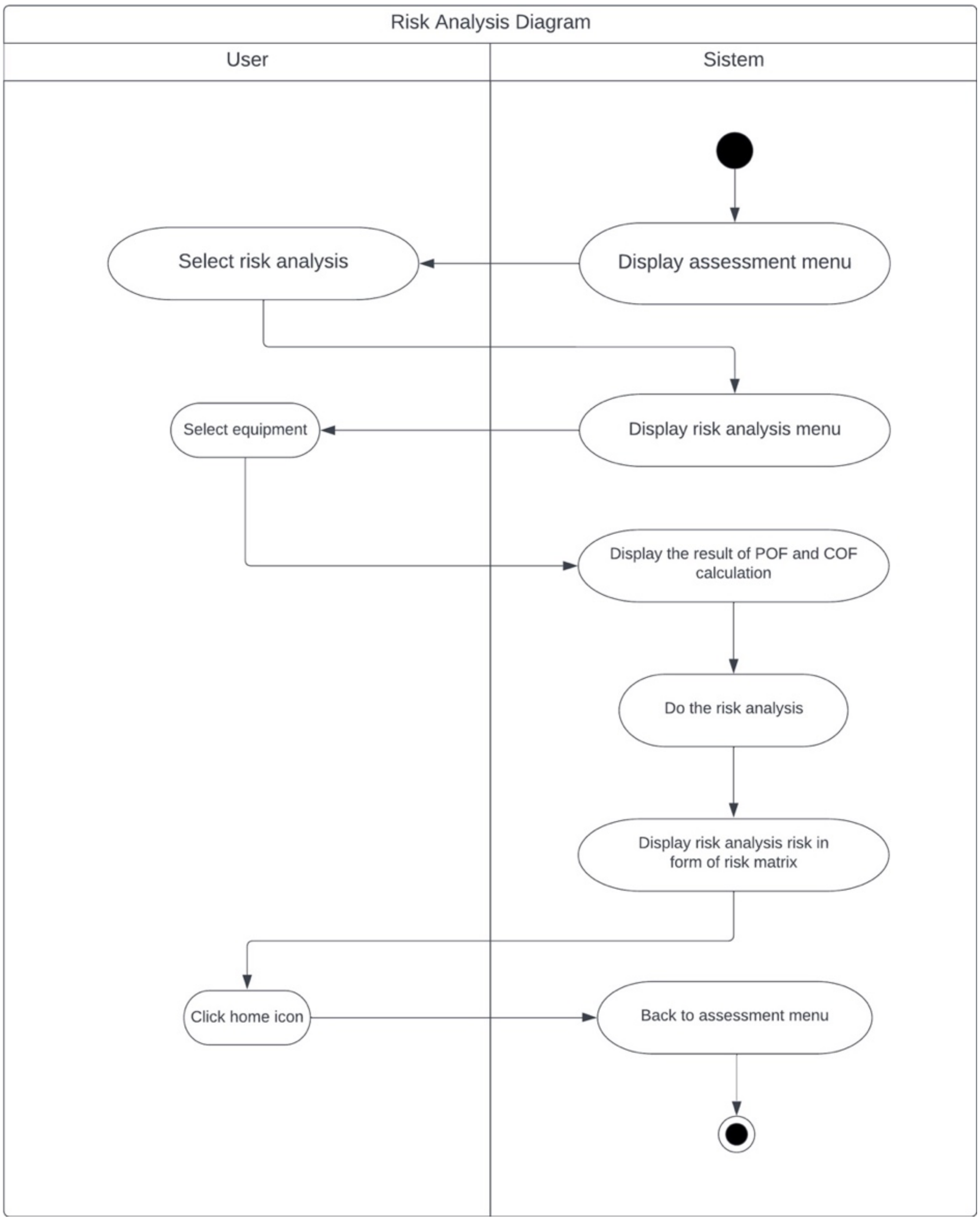

Figure 4. 12 Risk Analysis Menu Diagram

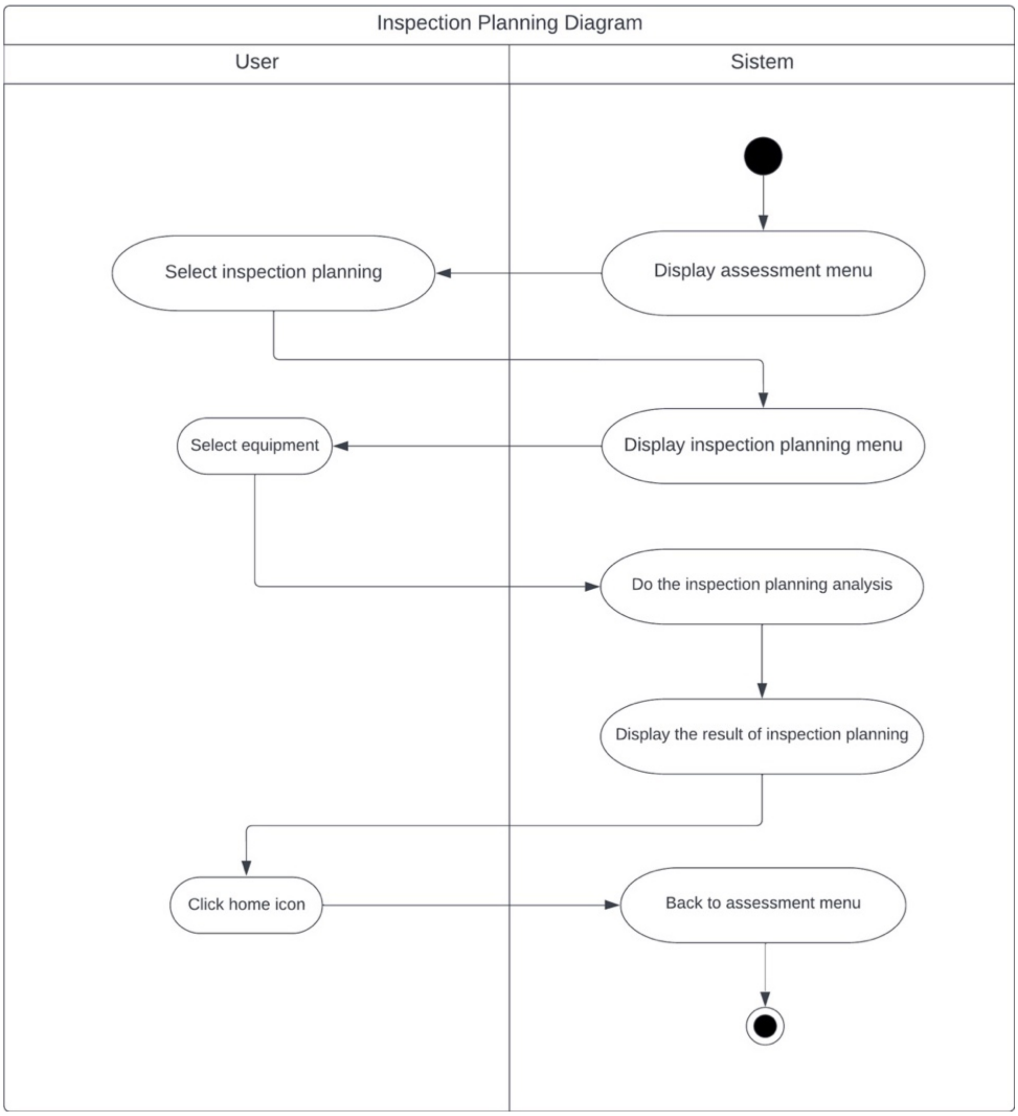

Figure 4. 13 Inspection Planning Menu Diagram

4.8.2 Entity Relationship Diagram (ERD)

Entity-Relationship Diagrams (ERDs) are graphical representations of the relationships between database entities. It illustrates the structure of a database by depicting the relationships between various entities. ERDs are commonly used to plan and organize data models in database design and development. In this creation and development of web applications project, there are several groups or folders of data in which there are data used in web application pages and calculations. ERD also describes the layout of databases, tables, and fields built in phpmyadmin. Several types of data are used such as INT, TINYINT, DOUBLE, ENUM, VARCHAR, DATE, TEXT, and MEDIUMTEXT. ERD that is used for this web apps development can be seen in **Figure 4. 14**.

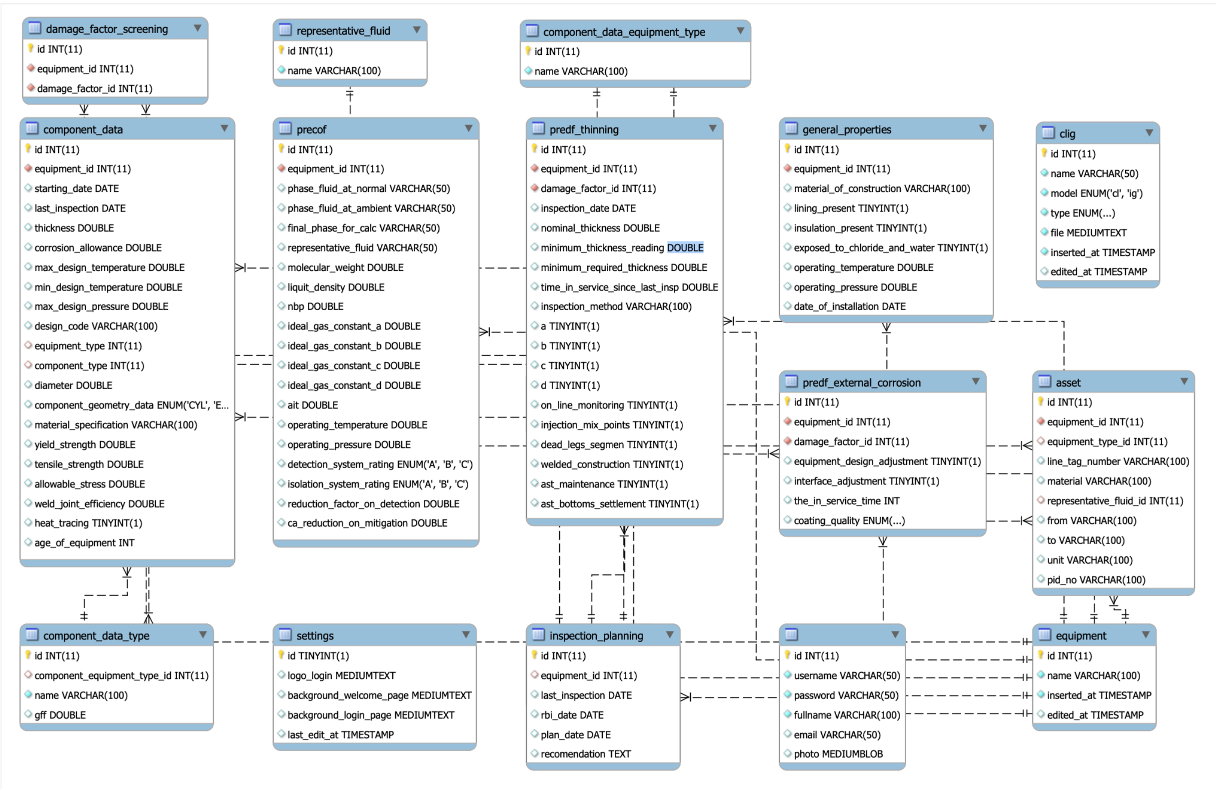

Figure 4. 14 Entity Relationship Diagram

4.9 Application Programming

In the php programming process, in general there are two ways, namely by native programming and programming using a framework. In this project, the method used is native programming which means it does not use a framework. There are several reasons such as easier, lighter (faster loading), easy to customize, easier to fix if there is an error, and easier to creating ideas in applications making. The coding on the web apps programming can be seen in **Appendix E**.

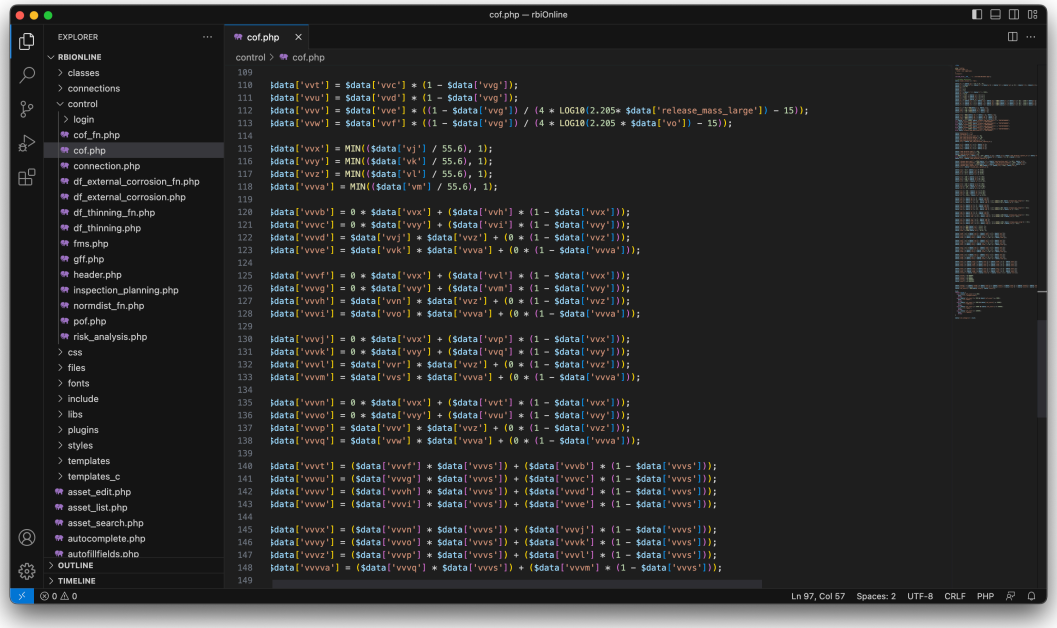

Figure 4. 15 Programming in Visual Studio Code

In making applications also requires a development environment that can be a space of programming files that have been created, the space is the localhost server. In the development of web apps in this study, Laragon is used as a localhost server. Laragon is a portable, isolated, fast, and powerful universal development environment especially for php. Laragon is great for building and managing modern web applications because it focuses on performance designed with stability, simplicity, and flexibility.

4.10 Application Domain and Web Hosting

After the application has begun to be developed on the localhost server, the next process is to make web apps can be run online (connected to the internet) at addresses with certain domains. The process is called web hosting.

Web hosting refers to the service of storing and providing access to websites on internet-connected infrastructure. When a website is created, it must be stored on a server and made accessible to visitors via the internet. Web hosting companies specialize in providing the infrastructure, resources, and technical support necessary to make the website accessible and operational online. In this project, web hosting is also used for monitoring the web apps development progress. Web hosting makes the author easier to find out the error. Figures below are the look of web hosting that is used by the author. The web hosting display can be seen in **Figure 4. 16.**

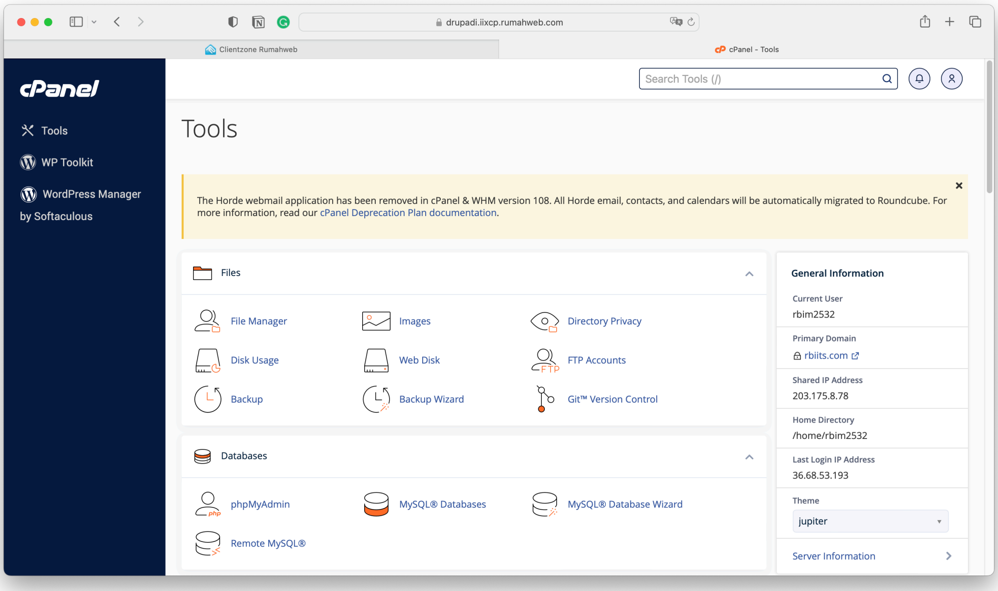

Figure 4. 16 Hosting Control Panel Display

In the hosting control panel, there are several tools that can be used such as files (to upload files and access them), databases (to access databases), domains (for pointing domains and hosting), and various other tools. In order to access the application with the desired domain or already provided by the user, pointing domain and hosting needs to be done. **Figure 4. 17** shows that the hosting is bound by the rbiits.com domain and the linked programming files are in the public_html folder.

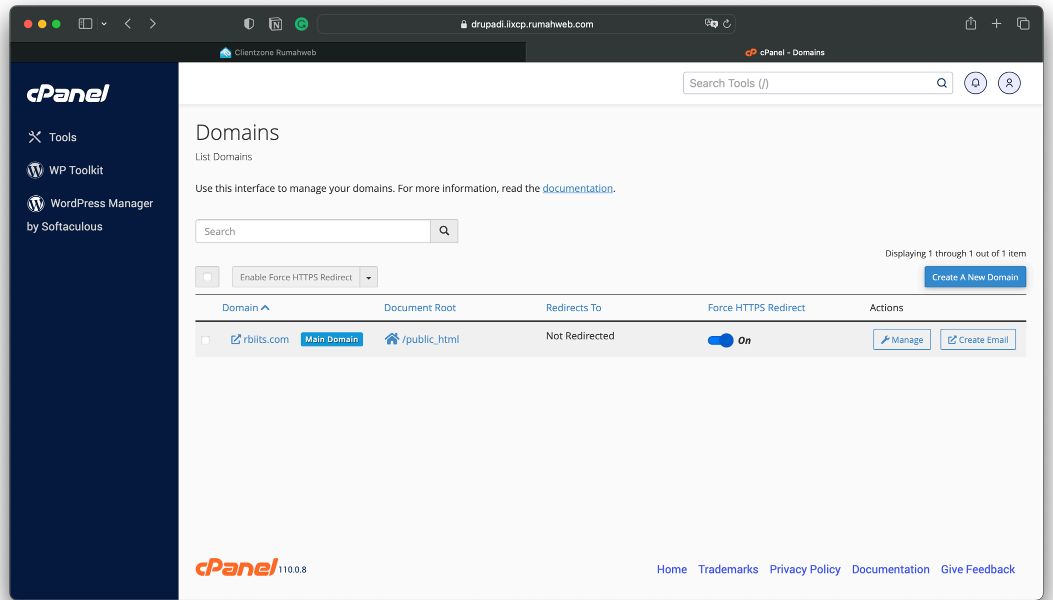

Figure 4. 17 Domains Page in Hosting Control Panel

After connecting between hosting and domain, the application can be accessed through the domain that has been registered. The information can be seen on the right side of the hosting control panel menu. In the tools section 'files' can be uploaded programming files that have been created so that when the application is accessed through the domain, then what is displayed is the same and in accordance with what is displayed on localhost. File uploading is done by uploading files that have a .zip extension. Once uploaded, the zip file can be unzipped. **Figure 4. 18** shows a collection of programming files that has been uploaded on the web host. The coding of these files can also be edited as shown in **Figure 4. 19**.

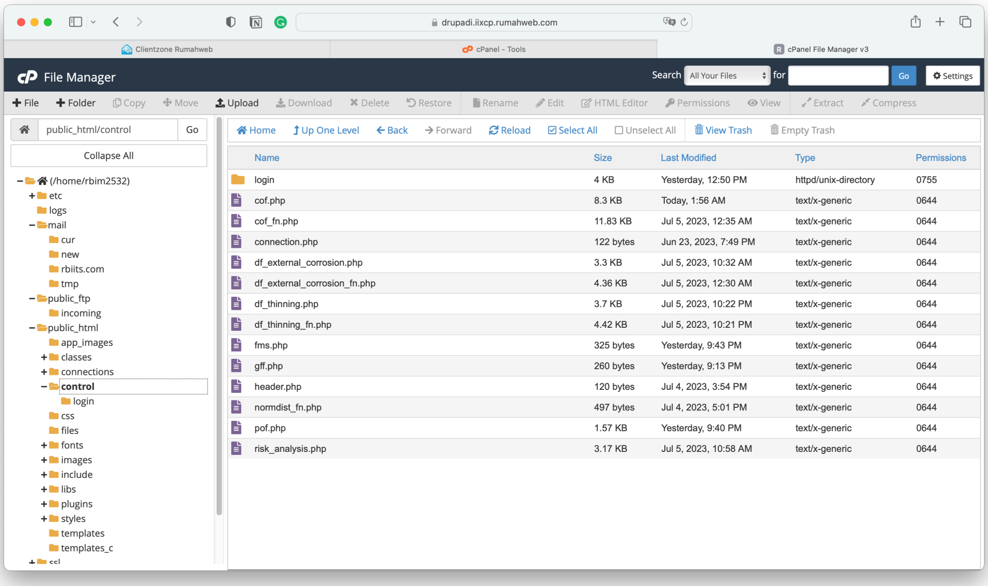

Figure 4. 18 Programming Data Sets in Shared Hosting

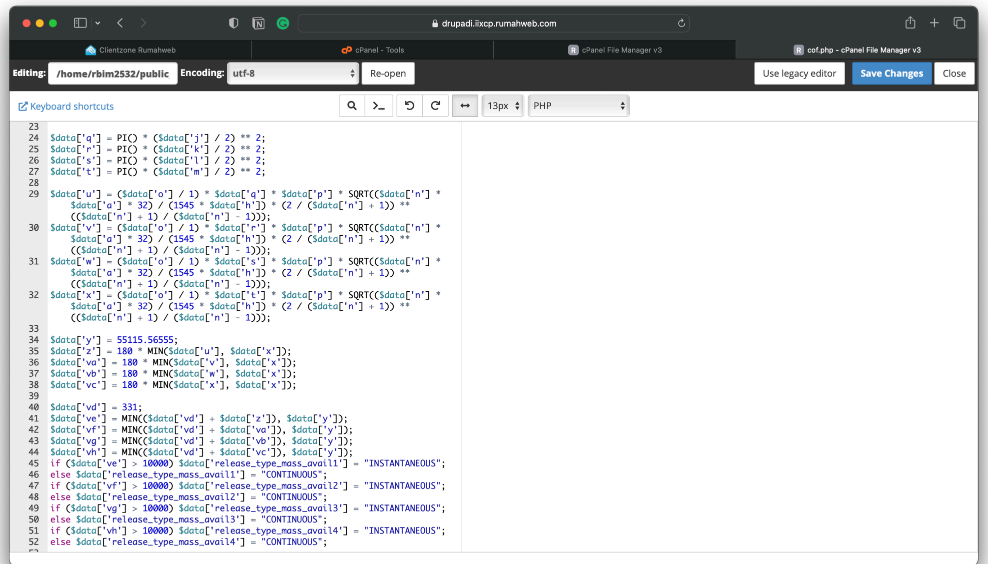

Figure 4. 19 Coding Display in Shared Hosting

4.11 Web Application Database

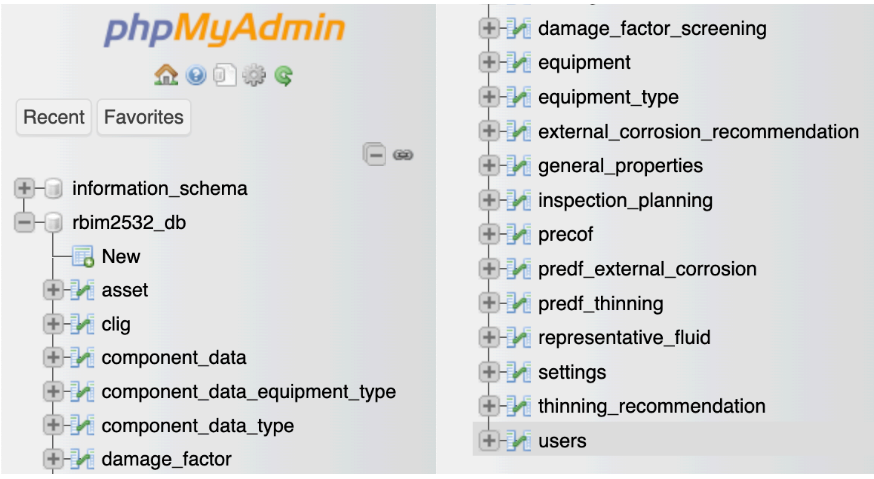

Figure 4. 20 Web Application Database Table

In this section, it will be shown and explained about the database implementation of the finished web application. **Figure 4.20** shows the arrangement of database tables that contain fields that have been added and also data from users that have been filled through data columns in the application. The database table here will be updated if the user changes input data or adds other recent data in the application.

a. Corrosion Loop and Inventory Group Table

Extra options

←T→	id	name	model	type	file	inserted_at
Edit Copy Delete	15	Overall PFD	ig	PFD	[{"name":"app_images\/Screenshot 2023-06-27 at 09....	2023-06-27 10:00:50
Edit Copy Delete	17	Sweet Gas KO Drum	ig	P&ID	[{"name":"app_images\/Screenshot 2023-06-27 at 10....	2023-06-27 10:04:48
Edit Copy Delete	18	Acid Gas Absorber	ig	P&ID	[{"name":"app_images\/Screenshot 2023-06-27 at 10....	2023-06-27 10:05:16
Edit Copy Delete	19	ACID GAS REMOVAL UNIT	cl	PFD	[{"name":"app_images\/Picture2_e7d1qdxt.jpg","usrN...	2023-07-09 06:37:12
Edit Copy Delete	20	Acid Gas Removal Unit	ig	PFD	[{"name":"app_images\/Picture4_2qx7jkfh.jpg","usrN...	2023-07-09 06:38:22
Edit Copy Delete	21	ACID GAS ABSORBER	cl	P&ID	[{"name":"app_images\/Picture3_dw8t388b.jpg","usrN...	2023-07-09 06:40:31
Edit Copy Delete	22	SWEET GAS KO DRUM	cl	P&ID	[{"name":"app_images\/Picture4_s5enjis4.jpg","usrN...	2023-07-09 06:40:56
Edit Copy Delete	23	340-PG-1001-10-06S3 [1]	cl	Asset Register	[{"name":"app_images\/Picture1_ykryluc5.jpg","usrN...	2023-07-09 08:54:16
Edit Copy Delete	26	340-PG-1001-10-06S3 [2]	cl	Asset Register	[{"name":"app_images\/Picture2_rlbqmi3h.jpg","usrN...	2023-07-09 08:59:41
Edit Copy Delete	29	Registered Pipe - CL1	cl	Asset Register	[{"name":"app_images\/Screenshot 2023-07-13 at 10....	2023-07-13 11:01:17
Edit Copy Delete	30	Registered Vessel - CL1	cl	Asset Register	[{"name":"app_images\/Screenshot 2023-07-13 at 10....	2023-07-13 11:02:13
Edit Copy Delete	31	Registered Pipe - IG1	ig	Asset Register	[{"name":"app_images\/Screenshot 2023-07-13 at 11....	2023-07-13 11:03:51
Edit Copy Delete	32	Registered Vessel - IG1	ig	Asset Register	[{"name":"app_images\/Screenshot 2023-07-13 at 11....	2023-07-13 11:05:11

Figure 4. 21 Corrosion Loop and Inventory Group Table

Figure 4. 21 shows several fields in the corrosion loop and invetory group table such as file name, model in the form of corrosion loop or inventory group, type in the form of PFD, PID, or asset register, file uploaded by user and file upload date.

b. Asset Data Table

Extra options

←T→	id	equipment_id	equipment_type_id	line_tag_number	material
☐ Edit Copy Delete	1	2	12	340-PG-1001-10-06S3	Carbon Steel ASTM A106 Gr B

representative_fluid_id	from	to	unit	pid_no
1	Acid Gas Absorber (340-T-1001)	Sweet Gas KO Drum (340-D-1002)	AGRU - SRU	MTDF-PR-340-PID-1002, MTDF-PR-340-PID-1009

Figure 4. 22 Asset Data Table

Figure 4. 22 shows several fields in the asset data table such as equipment type, line/tag number, material, representative fluid, from, to, unit, and number of PID.

Extra options

←T→	id	name
☐ Edit Copy Delete	1	C1 - C2 (Methane, Ethane, Ethylene, LNG, Fuel Gas)
☐ Edit Copy Delete	8	C13 - C16 (Jet Fuel, Kerosene, Atmospheric Gas Oil...
☐ Edit Copy Delete	9	C17 - C25 (Gas Oil, Typical Crude)
☐ Edit Copy Delete	10	C25+ (Residuum, Heavy Crude, Lube Oil, Seal Oil)
☐ Edit Copy Delete	2	C3 - C4 (Propane, Butane, Isobutane, LPG)
☐ Edit Copy Delete	3	C5 (Pentane)
☐ Edit Copy Delete	4	C6 - C8 (Gasoline, Naphtha, Light Straight Run, He...
☐ Edit Copy Delete	6	C9 - C12 (Diesel, Kerosene)

Figure 4. 23 Representative Fluid Table

Figure 4. 23 shows data related to the representative fluid that the user can choose such as C1-C2 (methane, ethane, ethylene, LNG, fuel gas), C3-C4 (propane, butane, isobutane, LPG), C5 (pentane), C6-C8 (gasoline, naptha, light straight run, heptane), C9-C12 (diesel, kerosene), C13-C16 (jet fuel, kerosene, atmospheric gas oil), C17-C25 (gas oil, typical crude), and C25+ (residuum, heavy crude, lube oil, seal oil).

c. General Properties Table

Extra options

←T→	id	equipment_id	material_of_construction	lining_present
☐ Edit Copy Delete	1	2	Carbon or Low Alloy	1

insulation_present	exposed_to_chloride_and_water	operating_temperature	operating_pressure	date_of_installation
0	1	20	6.16	2017-03-09

Figure 4. 24 General Properties Table

Figure 4. 24 shows several fields in the general properties table such as material of construction, lining present, insulation present, exposed to chloride and water, operating temperature, operating pressure, and date of installation.

d. Component Data Table

Extra options

←T→	id	equipment_id	starting_date	last_inspection	thickness	corrosion_allowance
Edit Copy Delete	1	2	2017-03-09	2022-09-24	14.15	0.118

max_design_temperature	min_design_temperature	max_design_pressure	design_code	equipment_type
204.4	-28.9	10.2	ASME B31.3	10

component_type	diameter	component_geometry_data	material_specification	yield_strength	tensile_strength
23	10	CYL	ASTM A106 Gr B	240	415

allowable_stress	weld_joint_efficiency	heat_tracing	age_of_equipment
138	1	0	6

Figure 4. 25 Component Data Table

Figure 4. 25 shows several fields in the component data table such as starting date, last inspection date, thickness, corrosion allowance, max. design temperature, min. design temperature, max. design pressure, design code, equipment type, component type, diameter, component geometry data, material spesification, yield strength, tensile strength, allowable stress, weld joint efficiency, heat tracing, and age of equipment.

e. Equipment Type Table

Extra options

←T→	id	name
Edit Copy Delete	12	Compressor
Edit Copy Delete	11	Heat Exchanger
Edit Copy Delete	10	Pipe
Edit Copy Delete	9	Pump
Edit Copy Delete	8	Tank650
Edit Copy Delete	7	Vessel/FinFan

Figure 4. 26 Equipment Type Table

Figure 4. 26 shows data related to the equipment type that the user can choose such as vessel/finfan, tank650, pump, pipe, heat exchanger, and compressor.

f. Component Type Table

Extra options

←T→				id	component_equipment_type_id	name	gff
☐	Edit	Copy	Delete	7	7	COLMID	0.0000306
☐	Edit	Copy	Delete	8	7	COLTOP	0.0000306
☐	Edit	Copy	Delete	9	7	REACTOR	0.0000306
☐	Edit	Copy	Delete	10	7	DRUM	0.0000306
☐	Edit	Copy	Delete	11	7	FILTER	0.0000306
☐	Edit	Copy	Delete	12	7	FINFAN	0.0000306
☐	Edit	Copy	Delete	13	7	COLBTM	0.0000306
☐	Edit	Copy	Delete	14	7	KODRUM	0.0000306
☐	Edit	Copy	Delete	15	8	COURSE-1-10	0.0001
☐	Edit	Copy	Delete	16	8	TANKBOTTOM	0.00072
☐	Edit	Copy	Delete	17	9	PUMP1S	0.0000306
☐	Edit	Copy	Delete	18	9	PUMPR	0.0000306
☐	Edit	Copy	Delete	19	9	PUMP2S	0.0000306
☐	Edit	Copy	Delete	20	10	PIPE-GT16	0.0000306
☐	Edit	Copy	Delete	21	10	PIPE-16	0.0000306
☐	Edit	Copy	Delete	22	10	PIPE-12	0.0000306
☐	Edit	Copy	Delete	23	10	PIPE-10	0.0000306
☐	Edit	Copy	Delete	24	10	PIPE-8	0.0000306
☐	Edit	Copy	Delete	25	10	PIPE-6	0.0000306
☐	Edit	Copy	Delete	26	10	PIPE-4	0.0000306
☐	Edit	Copy	Delete	27	10	PIPE-2	0.0000306
☐	Edit	Copy	Delete	28	10	PIPE-1	0.0000306
☐	Edit	Copy	Delete	29	11	HEXTS	0.0000306
☐	Edit	Copy	Delete	30	11	HEXSS	0.0000306
☐	Edit	Copy	Delete	31	12	COMPR	0.0000306

Figure 4. 27 Component Type Table

Figure 4. 27 shows data related to the component type that the user can choose such as kodrum, colbtm, finfan, filter, drum, reactor, coltop, and colmid if the user chose vessel/finfan as the equipment type. If the user chose tank650 as the euipment type then tankbottom or course-1-10 can be chosen. If the user chose pipe as the equipment type, then pipe-1, pipe-2, pipe-4, pipe-6, pipe-8, pipe-10, pipe-12, pipe-16, or pipegt16 can be chosen. Likewise, with the types of pumps, heat exchanger, and compressor equipment, they have their own choices for the type of component.

g. Damage Factor Table

Extra options

				id	name	description
☐	Edit	Copy	Delete	1	Thinning	<p>This is a required factor that applies to all c...
☐	Edit	Copy	Delete	2	Component Lining	<p>The component includes a lining (either i...
☐	Edit	Copy	Delete	3	SCC - Caustic Cracking	<p>The Component is composed of a carbon or low al...
☐	Edit	Copy	Delete	4	SCC - Amine Cracking	<p>The component is composed of a carbon or low al...
☐	Edit	Copy	Delete	5	SCC - Sulfide Stress Cracking	<p>The component is composed of carbon or low allo...
☐	Edit	Copy	Delete	6	SCC - HIC/SOHIC-H2S	<p>The component is composed of a carbon or low al...
☐	Edit	Copy	Delete	7	SCC - Alkaline Carbonate Stress Corrosion Cracking	<p>The component is composed of a carbon or low al...
☐	Edit	Copy	Delete	8	SCC - Polythionic Acid Corrosion Cracking	<p>The component is composed of a nickel-based all...
☐	Edit	Copy	Delete	9	SCC - Chloride Stress Corrosion Cracking	<p>The component is composed of a austenitic stain...
☐	Edit	Copy	Delete	10	SCC - Hydrogen Stress Cracking in Hydrofluoric Aci...	<p>The component is composed of a carbon or low al...
☐	Edit	Copy	Delete	11	SCC - HIC/SOHIC-HF	<p>The component is composed of a carbon or low al...
☐	Edit	Copy	Delete	12	External Corrosion - Ferritic Component	<p>Select this factor if the component is un-insul...
☐	Edit	Copy	Delete	13	Corrosion Under Insulation (CUI) - Ferritic Compon...	<p>Component and/or locations are suspect. i.e., v...
☐	Edit	Copy	Delete	14	ExtCISCC - Austenitic Component	<p>The component is composed of austenitic stainle...
☐	Edit	Copy	Delete	15	External CUI CISCC - Austenitic Component	<p>The component is composed of austenitic stainle...
☐	Edit	Copy	Delete	16	Brittle Fracture	<p>The material is composed of carbon steel or low...
☐	Edit	Copy	Delete	17	Low Alloy Steel Embrittlement	<p>The material is composed of 1Cr- 0.5Mo, 1.25Cr-...
☐	Edit	Copy	Delete	18	High Temperature Hydrogen Attack (HTHA)	<p>The component is composed of carbon steel, C-&f...
☐	Edit	Copy	Delete	19	885 °F Embrittlement	<p>The material is composed of high chromium (>...
☐	Edit	Copy	Delete	20	Sigma Phase Embrittlement	<p>The material is composed of austenitic stainles...
☐	Edit	Copy	Delete	21	Piping Mechanical Fatigue	<p>Select this factor if the component is a pipe a...

Figure 4. 28 Damage Factor Table

Figure 4. 27 shows data related to the damage factor type and its description that the user can choose on damage factor selection menu in the web application.

h. Damage Factor Screening Table

Extra options

				id	equipment_id	damage_factor_id
☐	Edit	Copy	Delete	37	2	1
☐	Edit	Copy	Delete	39	2	12

Figure 4. 29 Damage Factor Screening Table

Figure 4. 27 shows data related to the the result of damage factor screening. As can be seen in the damage factor table, the selected damage factors are damage factor number 1 and number 12 which are thinning and external corrosion.

i. Pre DF Thinning Table

Extra options

				id	equipment_id	damage_factor_id	inspection_date	nominal_thickness
☐	Edit	Copy	Delete	6	2	1	2022-09-24	15.09

minimum_thickness_reading	minimum_required_thickness	time_in_service_since_last_insp	inspection_method	a	b	c	d
14.15	12.98	1	NDT	0	0	1	0

on_line_monitoring	injection_mix_points	dead_legs_segmen	welded_construction	ast_maintenance	ast_bottoms_settlement
0	1	1	1	1	0

Figure 4. 30 Pre DF Thinning Table

Figure 4. 30 shows several fields in the pre df thinning table such as inspection date, nominal thickness, minimum thickness reading, minimum required thickness, time in-service since last inspection, inspection method, inspection effectiveness, and the presence of on-line monitoring, injection mix points, dead-legs segmen, welded construction, ast maintenance, and ast bottom settlement.

j. Pre DF External Corrosion Table

Extra options

←T→				id	equipment_id	damage_factor_id	equipment_design_adjustment	interface_adjustment	the_in_service_time	coating_quality
☐	Edit	Copy	Delete	1	2	12	0	0	6	Medium

Figure 4. 31 Pre DF External Corrosion Table

Figure 4. 31 shows several fields in the pre df external corrosion table such as the presence of equipment design adjustment, the presence of interface adjustment, the in-service time, and coating quality.

k. Pre Consequence of Failure Table

Extra options

←T→				id	equipment_id	phase_fluid_at_normal	phase_fluid_at_ambient	final_phase_for_calc
☐	Edit	Copy	Delete	1	2	Gas	Gas	Gas

representative_fluid	molecular_weight	liquit_density	nbp	ideal_gas_constant_a	ideal_gas_constant_b	ideal_gas_constant_c
C1 - C2	23	15.639	-193	12.3	0.015	-0.0000287

ideal_gas_constant_d	ait	operating_temperature	operating_pressure	detection_system_rating	isolation_system_rating
-0.0000000013	1036	30	893	B	C

mass_inv	mass_comp	reduction_factor_on_detection	ca_reduction_on_mitigation
55115.566	331	0	0.15

Figure 4. 32 Pre Conseqeuence of Failure Table

Figure 4. 32 shows several fields in the pre consequence of failure table such as phase fluid at normal operating (storage) conditions, phase of fluid at ambient (after release) conditions, final phase for calculation, representative fluid, molecular weight, liquid density, NBP, ideal gas constant A, ideal gas constant B, ideal gas constant C, ideal gas constant D, AIT, operating temperature, operating pressure, detection system rating, isolation system rating, mass inventory, mass component, reduction factor on detection, and reduction factor on mitigation.

l. Inspection Planning Table

Extra options

	id	equipment_id	last_inspection	last_inspection_effectiveness_thinning	last_inspection_effectiveness_external_corrosion	rbi_date	risk_target
Edit Copy Delete	1	2	2022-09-24	C	C	2023-07-14	2

Figure 4. 33 Inspection Planning Table

Figure 4. 33 shows several fields in the inspection planning table such as last inspection date, last inspection effectiveness rating for thinning and external corrosion, rbi date, and risk target.

m. Thinning Inspection Recommendations Table

Extra options

	id	effectiveness	intrusive	non_intrusive
Edit Copy Delete	1	A	<p>For the total surface area:</p> <p>>50% vis...	<p>For the total surface area: 100% UT/RT of CML&r...
Edit Copy Delete	2	B	<p>For the total surface area:</p> <p> >2...	<p>For the total surface area: OR >75% spot UT<...
Edit Copy Delete	3	C	<p>For the total surface area: </p> <p>>5...	<p>For the total surface area:</p> <p>>50% spo...
Edit Copy Delete	4	D	<p>For the total surface area:</p> <p><5% visu...	<p>For the total surface area: </p> <p>>2...
Edit Copy Delete	5	E	<p>Ineffective inspection technique/plan was utili...	<p>Ineffective inspection technique/plan was utili...

Figure 4. 34 Thinning Inspection Recommendations Table

Figure 4. 34 shows data related to the thinning inspection recommendations table. The data in this table will be linked to the control so that when the user has selected the last inspection effectiveness rating, the system can provide recommendations according to the data in the table.

n. External Corrosion Inspection Recommendations Table

Extra options

	id	effectiveness	text
Edit Copy Delete	1	A	<p>Visual inspection of >95% of the exposed sur...
Edit Copy Delete	2	B	<p>Visual inspection of >60% of the exposed sur...
Edit Copy Delete	3	C	<p>Visual inspection of >30% of the exposed sur...
Edit Copy Delete	4	D	<p>Visual inspection of >5% of the exposed surf...
Edit Copy Delete	5	E	<p>Ineffective inspection technique/plan was utili...

Figure 4. 35 External Corrosion Inspection Recommendations Table

Figure 4. 35 shows data related to the external corrosion inspection recommendations table. The data in this table will be linked to the control so that when the user has selected the last inspection effectiveness rating, the system can provide recommendations according to the data in the table.

4.12 Web Application Interface

Web application interface consists of the visual and interactive elements presented on a web page, enabling users to navigate, input data, initiate actions, and obtain information without difficulty. The interface design of a web application has a significant impact on the user experience, and a well-structured and user-friendly interface is crucial to the success of the application. Key aspects of a web application interface include its layout, navigation, and visual design. The layout should be organized logically, ensuring that users can easily find what they need. Clear and intuitive navigation menus guide users to various sections and features, enhancing usability.

In this section, the appearance and functionality of the final web application will be showed and explained.

In **Figure 4. 17**, the welcome page looks like. On this page it needs to be made interesting as the first impression of the web apps that will be used. After the user presses the log in button, then the user will then go to the log in page, **Figure 4. 18**.

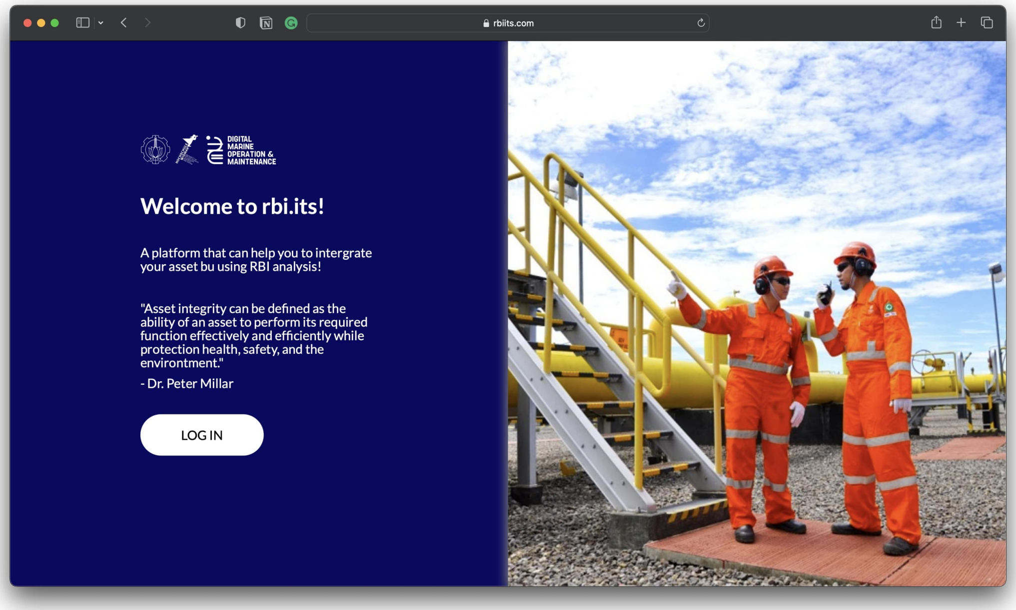

Figure 4. 36 Welcome Page

On the log in page, users can fill in their username and password before selecting the sign in button. This temporary web application is not designed for multi-users, so only one user is registered or commonly referred to as admin.

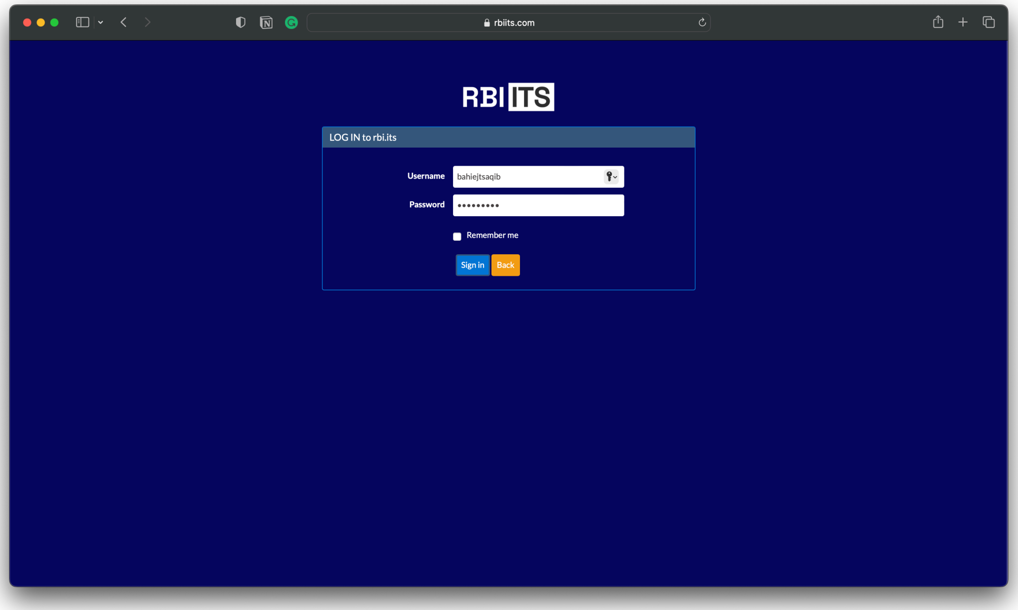

Figure 4. 37 Log In Page

After signing in, the first page that users will see is the assessment menu page. On this page, seven menu options are presented that are in accordance with the RBI assessment process to run. The process menus are corrosion loop & inventory group, component data identification, damage factor selection, probability of failure, consequence of failure, risk analysis, and also inspection planning. The assessment menu display can be seen in **Figure 4. 19** and **Figure 4. 20**.

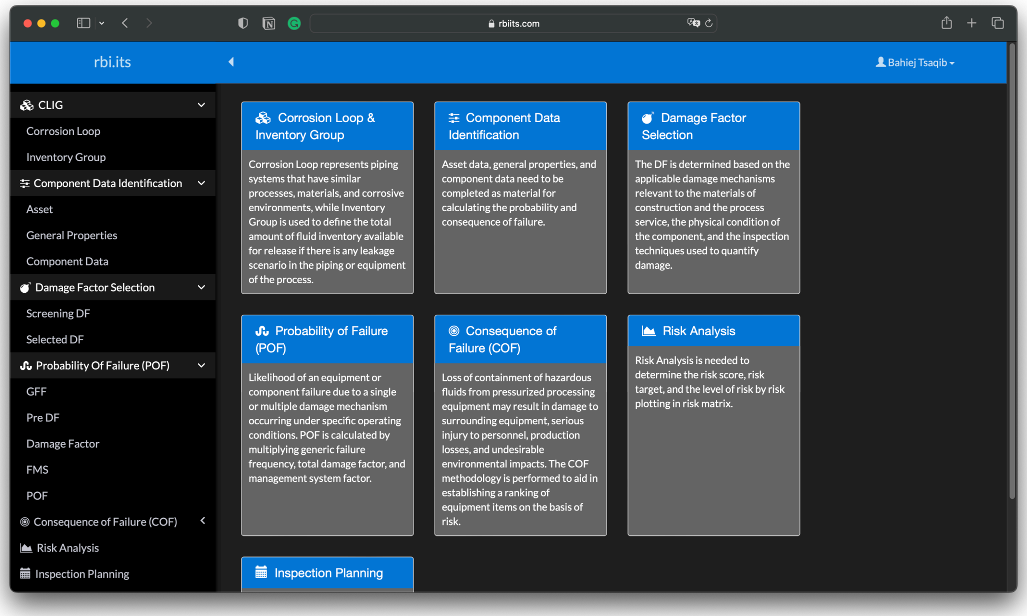

Figure 4. 38 Assessment Menu Page 1

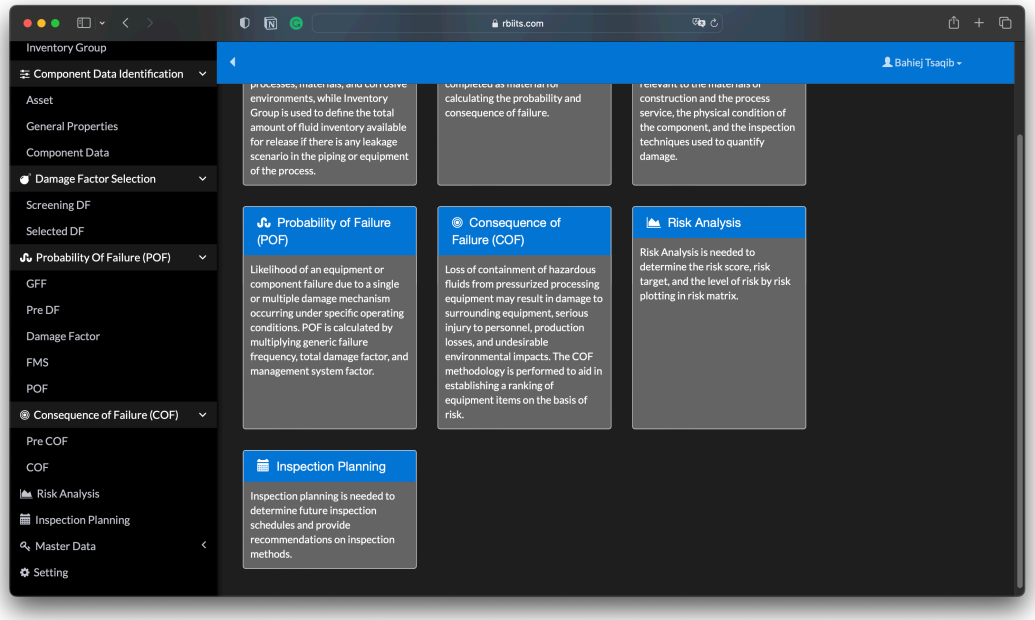

Figure 4. 39 Assessment Menu Page 2

In the corrosion loop & inventory group menu, users can upload dile or data related to corrosion loop and inventory group has been analyzed. Files that have been uploaded will be very helpful, especially when the results of the RBI assessment in this web app are presented. This menu page can be seen in **Figure 4. 21.** While in **Figure 4. 22** shows the display when the user presses the preview file that has been uploaded.

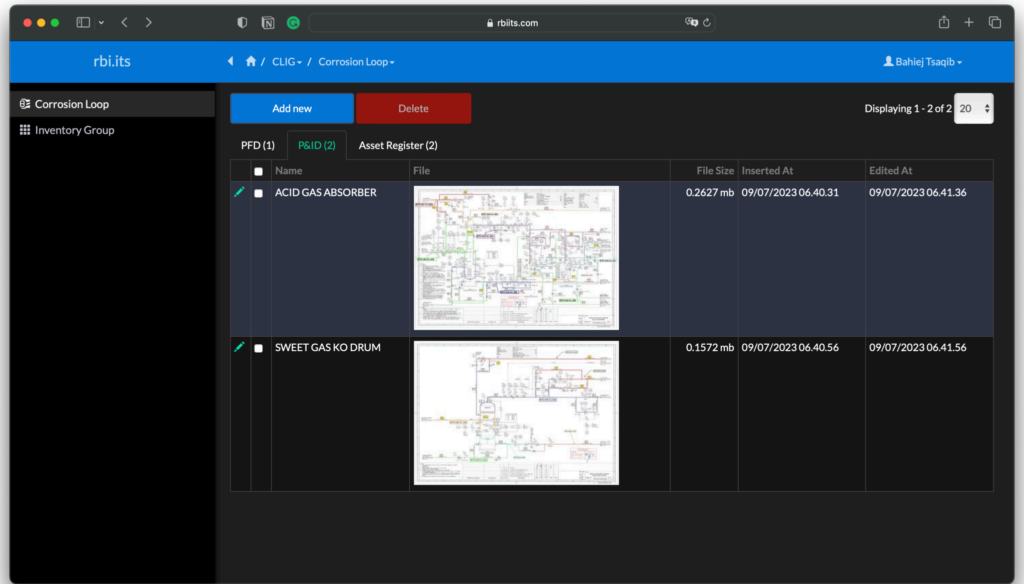

Figure 4. 40 Corrosion Loop & Inventory Menu Page 1

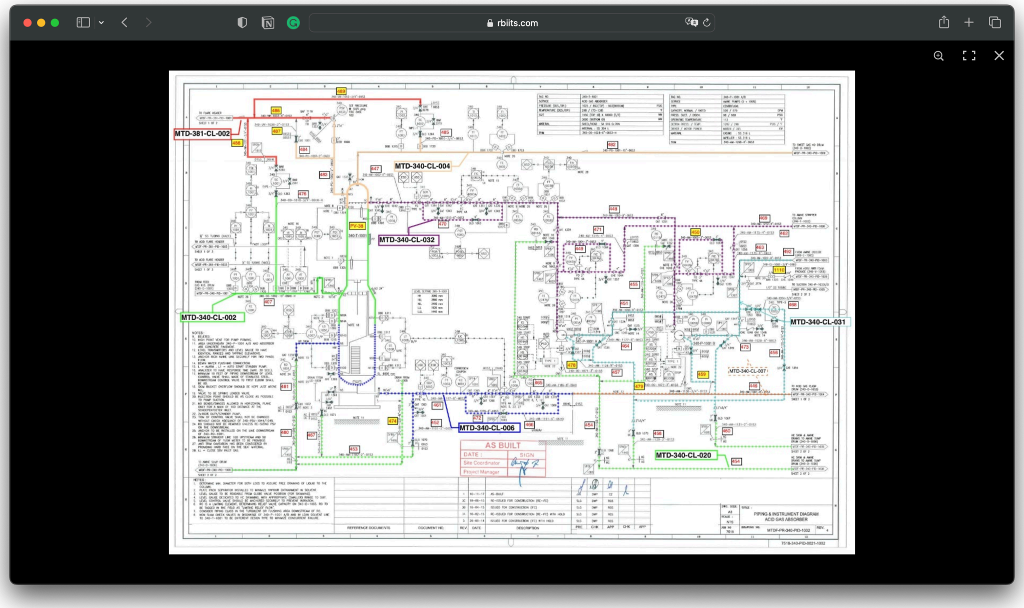

Figure 4. 41 Corrosion Loop & Inventory Menu Page 2

Furthermore, on the component data identification menu, there are three pages, namely, assets, general properties, and component data. But before going to those pages, the addition of equipment needs to be done first by the user. This is done by selecting the 'edit equipment' button. After the equipment is added, then the user can fill in the data and equipment information fields. Some of the data entered will affect the calculation of probability of failure. The component data identification menu page can be seen in **Figure 4. 23** to **Figure 4. 25**.

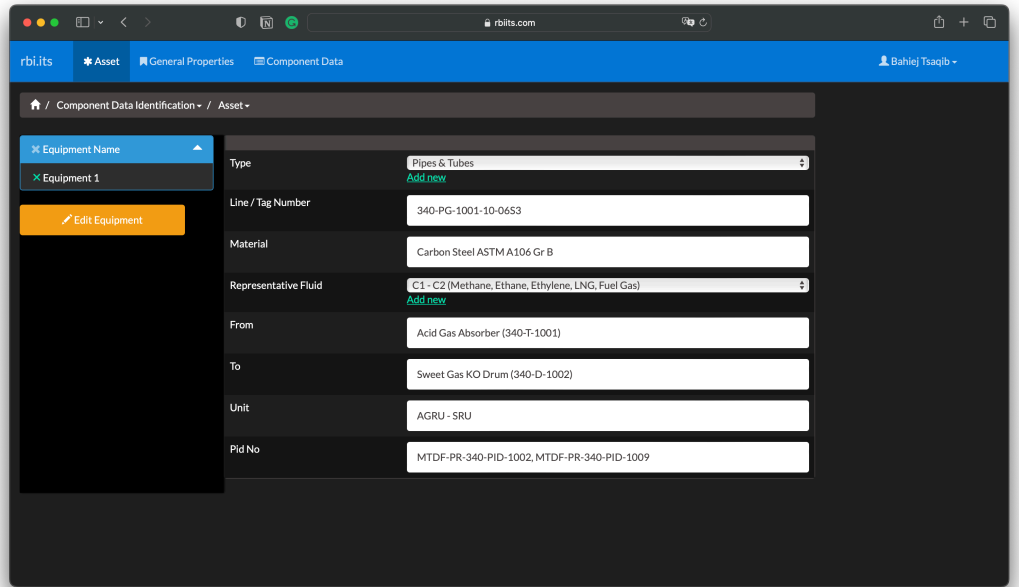

Figure 4. 42 Asset Data Page in Component Data Identification Menu

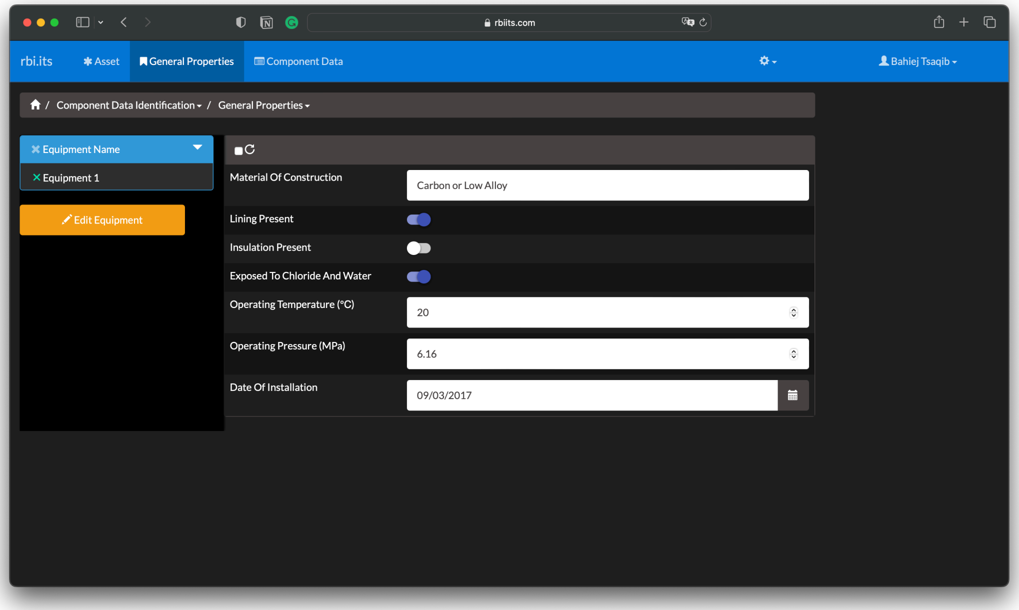

Figure 4. 43 General Properties Page in Component Data Identification Menu

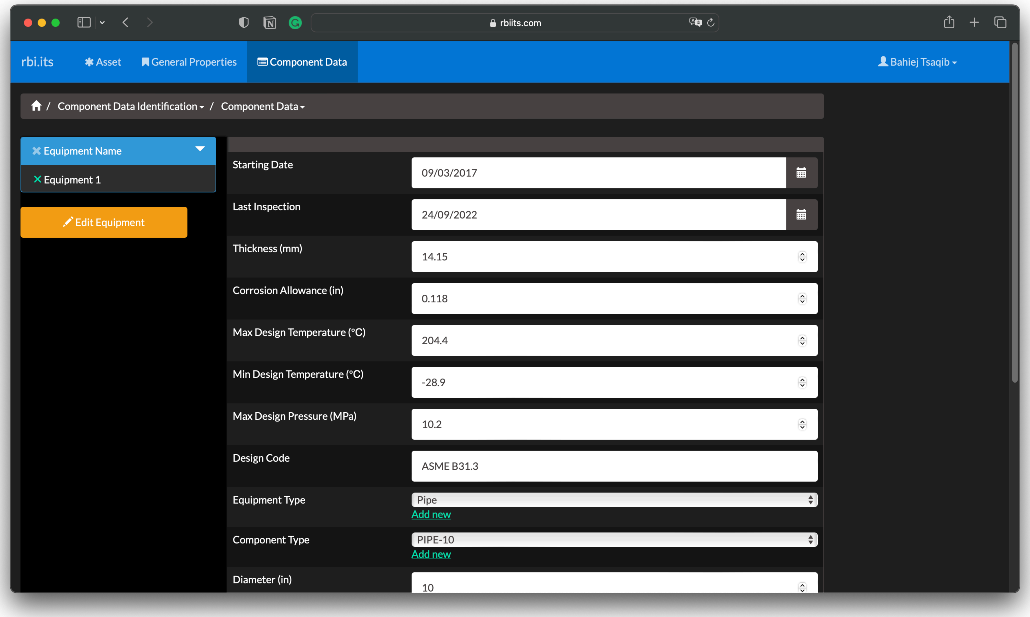

Figure 4. 44 Component Data Page in Component Data Identification Menu

After filling in the data and equipment information in the component data identification menu, then the user needs to go to the damage factor selection menu and do the screening process. The selection of this damage factor will affect the calculation in the probability of failure considering that the damage factor value is one of the variables to determine the POF score. There are two pages on this menu, namely the damage factor screening page and the selected damage factor page as can be seen in Figure 4. **26** and **Figure 4. 27**.

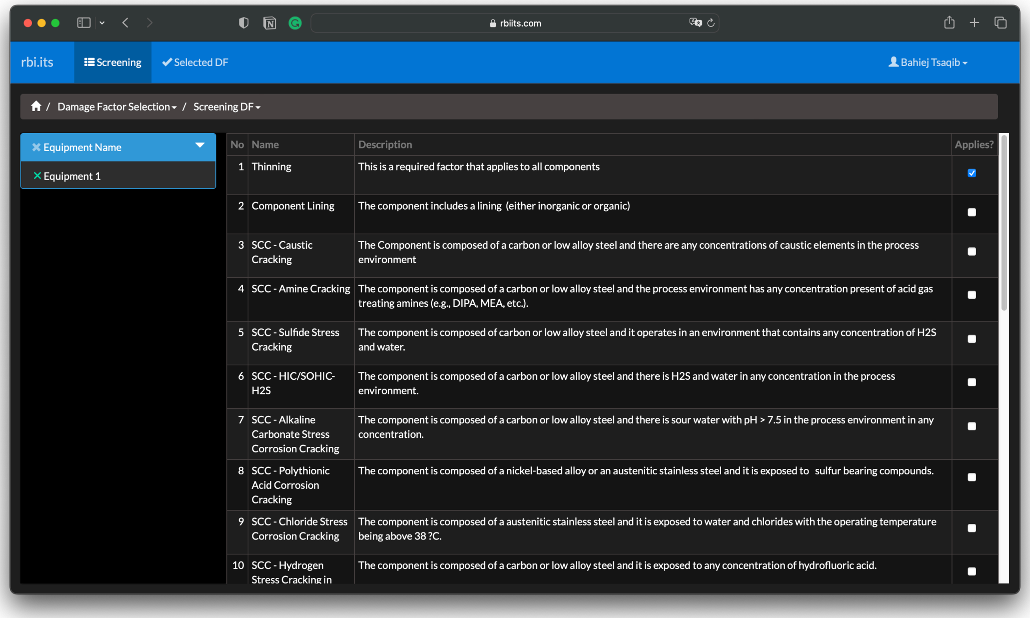

Figure 4. 45 Damage Factor Screening Page in Damage Factor Selection Menu

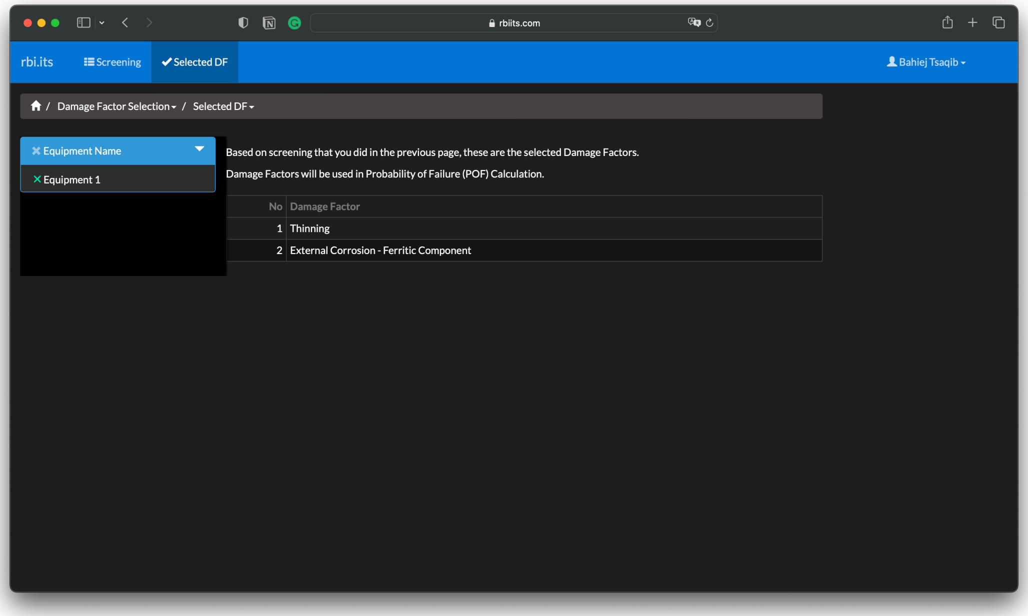

Figure 4. 46 Selected Damage Factor Page in Damage Factor Selection Menu

After selecting the damage factor selection process, the user then switches to the probability of failure menu. In this menu, there are five pages such as the generic failure frequency (GFF) page, pre damage factor page, damage factor page, system factor management (FMS) page, and a result page called the POF page. **Figure 4. 28** shows the GFF page as the first page in POF menu. On this page the system will display the total gff value based on the type of equipment and type of component selected by the user in the component data identification menu.

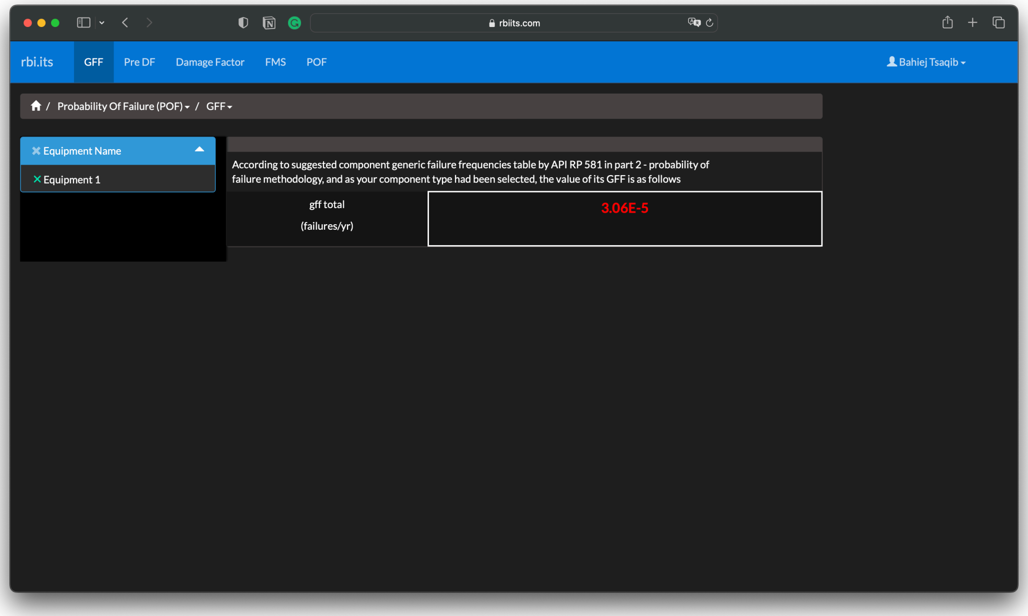

Figure 4. 47 GFF Page in Probability of Failure Menu

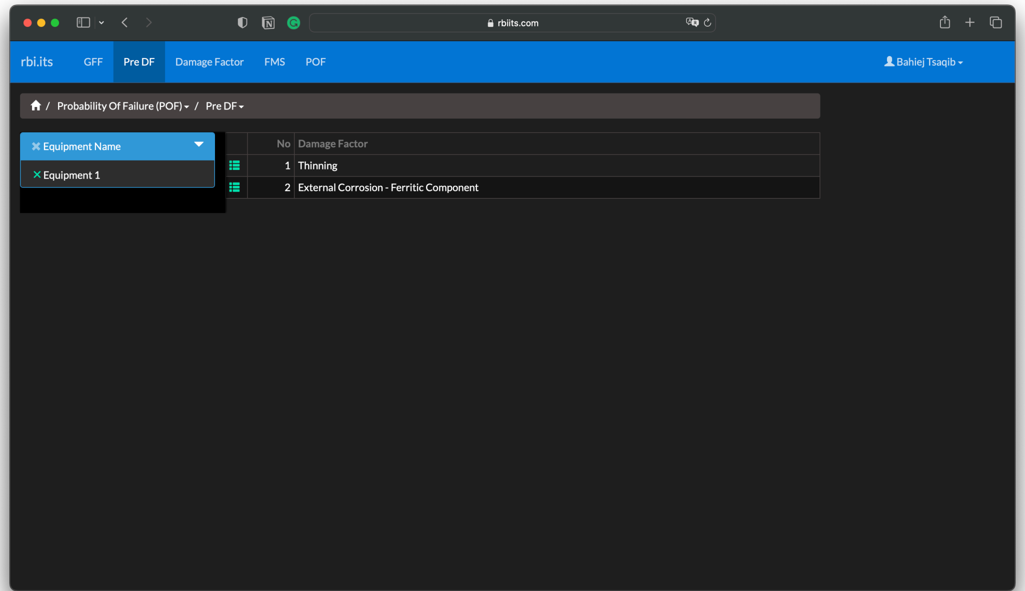

Figure 4. 48 Pre DF Page in Probability of Failure Menu

Furthermore, on the pre df menu, the selected damage factor is displayed, then when the user selects one of them, a column of data and information that needs to be filled in will appear. This filling helps the system to calculate the damage factor on the next page. **Figure 4. 30** and **Figure 4. 31** shows the pre df page for damage factor thinning and external corrosion.

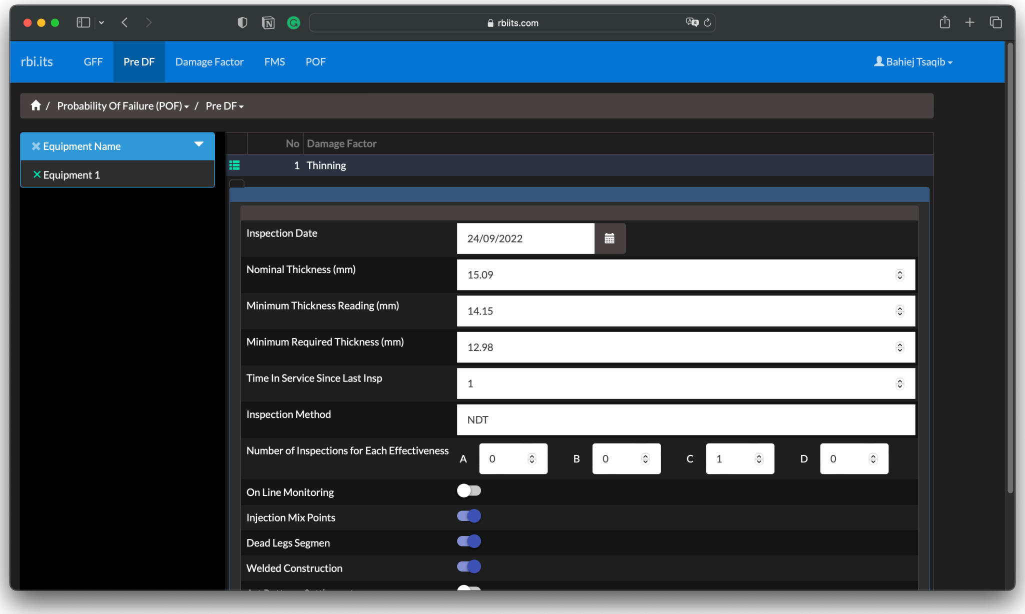

Figure 4. 49 Thinning Pre DF Page in Probability of Failure Menu

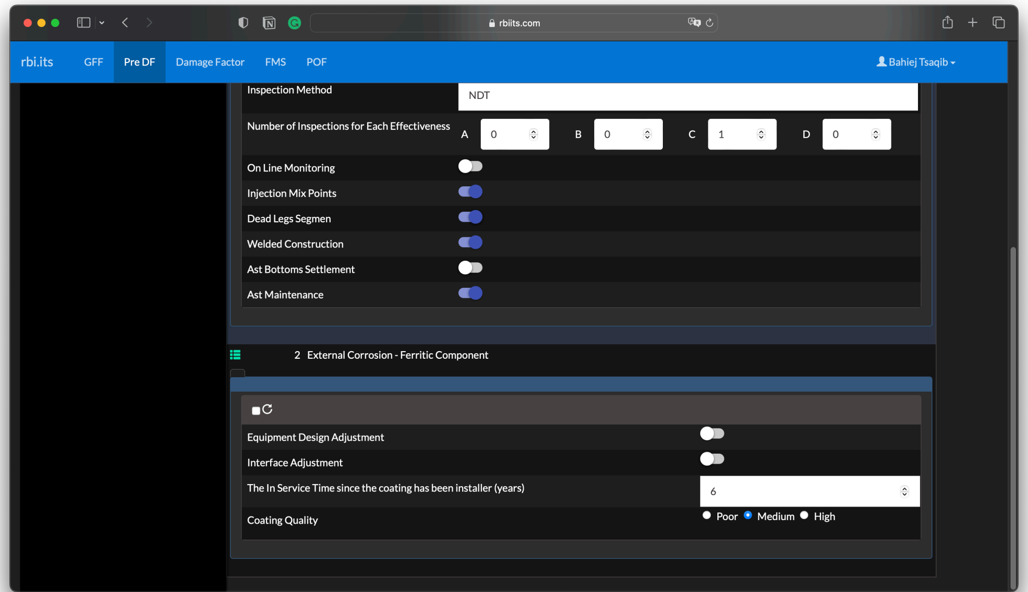

Figure 4. 50 Ext. Corrosion Pre DF Page in Probability of Failure Menu

On the next page, the damage factor page, the selected damage factor is displayed. When the user selects it, the system will show the results of the damage factor calculation for the selected damage factor. The order of the parameters in this calculation result is in accordance with what is needed to get the value of a damage factor. The results of this calculation are in accordance with the RBI assessment conducted manually by the author before starting to modeling this web application.

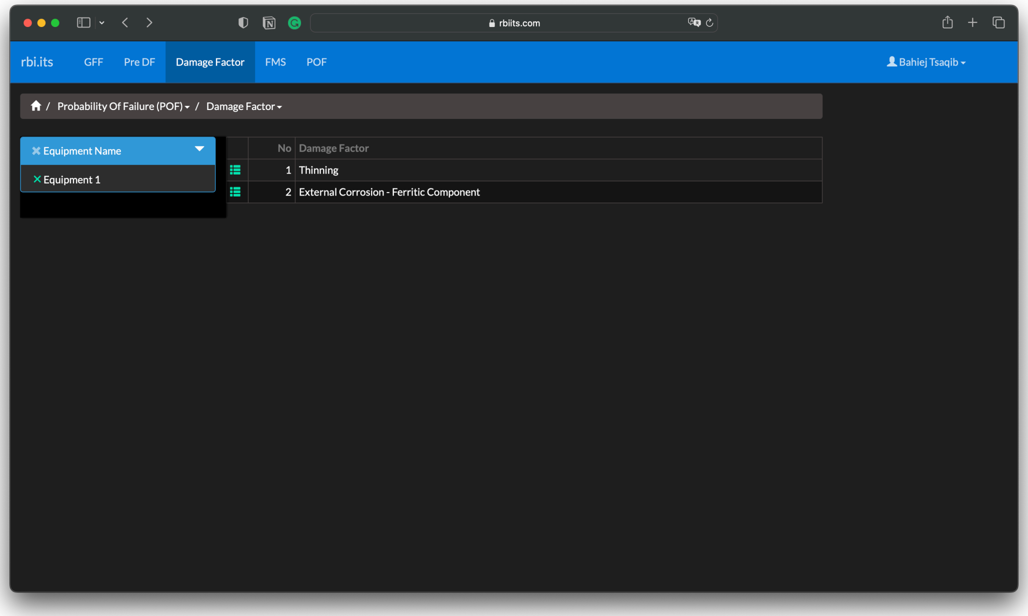

Figure 4. 51 Damage Factor Page in Probability of Failure Menu

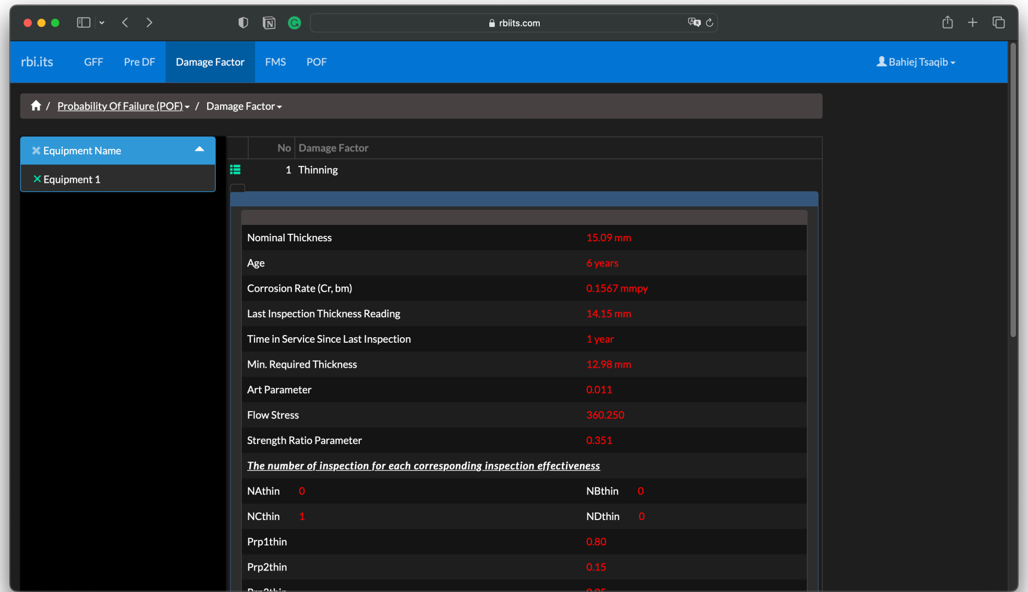

Figure 4. 52 Thinning Damage Factor Page in Probability of Failure Menu

Figure 4. 33 and **Figure 4. 34** shows the result of calculating the damage factor in thinning. While **Figure 4. 35** and **Figure 4. 36** shows the result of calculating the damage factor in external corrosion. These two damage factor values will later be added and will produce the Dftotal value as one of the parameters to determine the POF score.

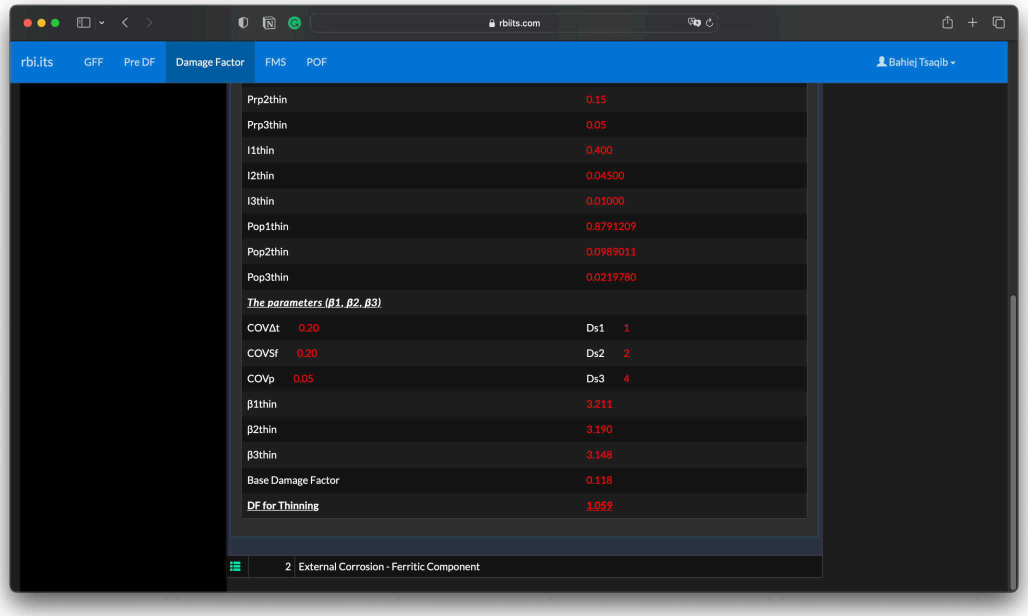

Figure 4. 53 Result of Thinning DF Calculation in Probability of Failure Menu

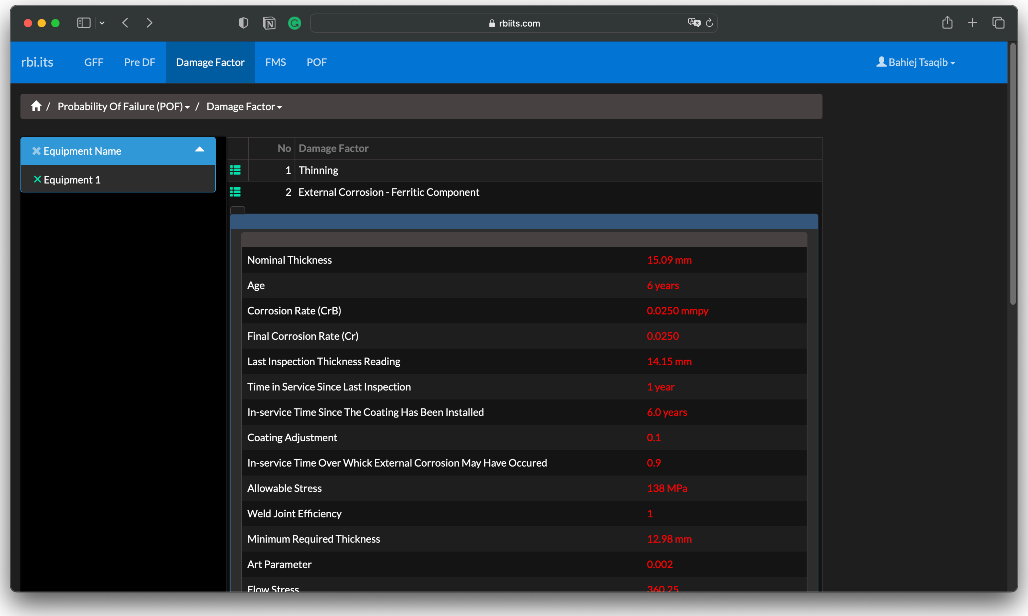

Figure 4. 54 Ext. Corrosion Damage Factor Page in Probability of Failure Menu

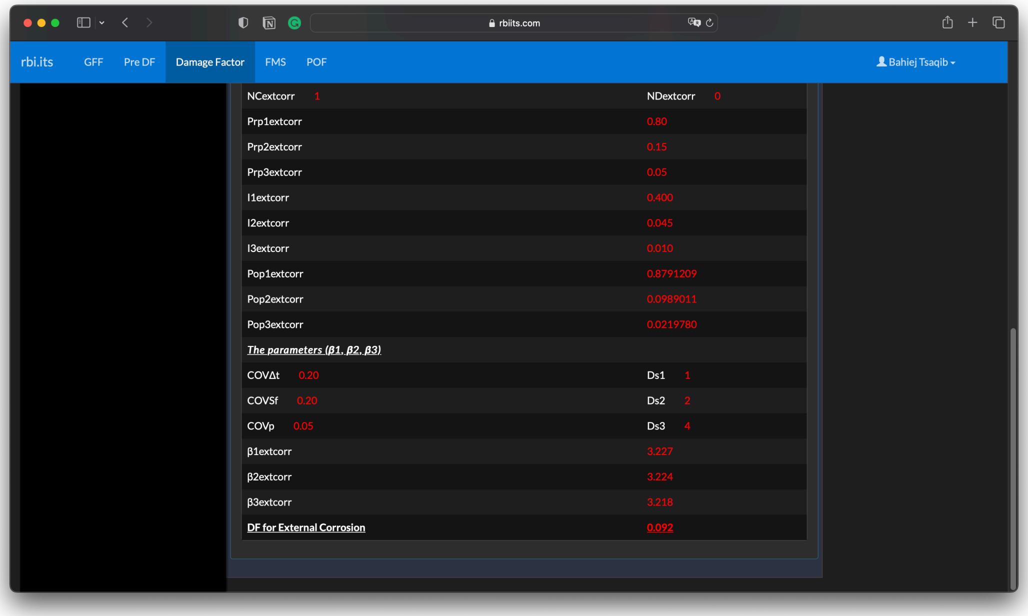

Figure 4. 55 Result of Ext. Corrosion DF Calculation in Probability of Failure Menu

The next page is the management system factor (FMS) page and the results of the POF calculation itself. On the FMS page, the results of the fmsscore value of 1 are displayed because in this RBI assessment the company is considered to have a good management system. FMS menu page can be seen in **Figure 4. 37**.

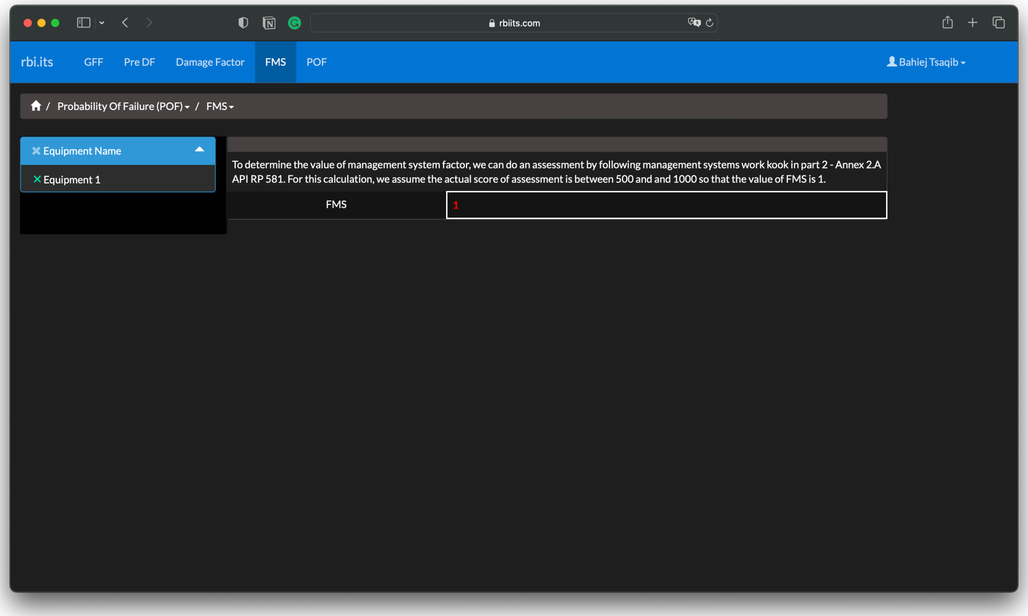

Figure 4. 56 Management System Factor Page in Probability of Failure Menu

In **Figure 4. 38** shows the POF page which displays the results of calculations to determine the score of probability of failure. The probability of failure score itself is obtained from the multiplication between the gff value, total damage factor, and fms score. In addition, the system also displays the POF category based on the POF score table in API RP 581.

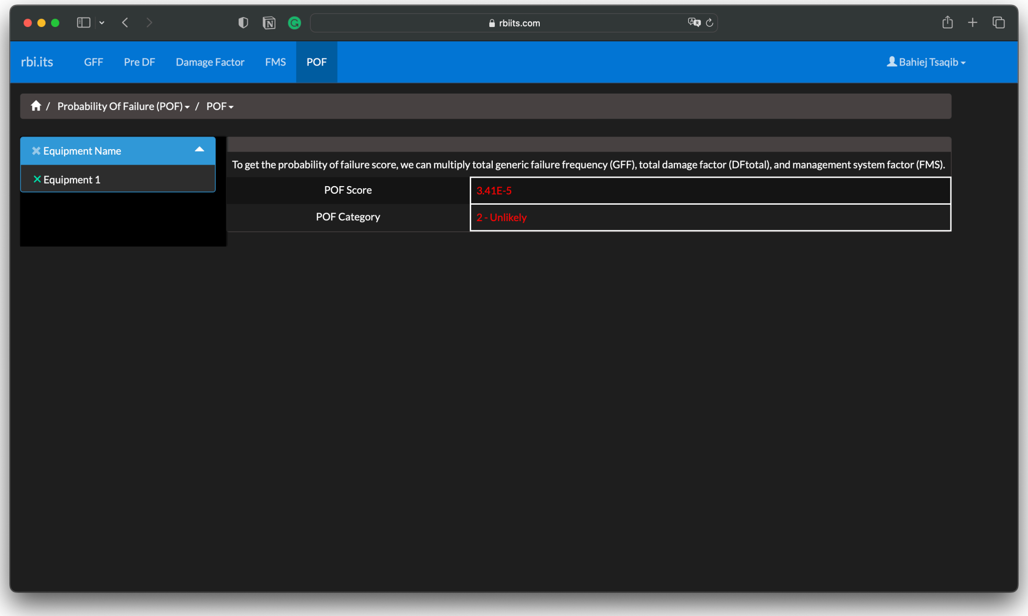

Figure 4. 57 Result of POF Calculation in Probability of Failure Menu

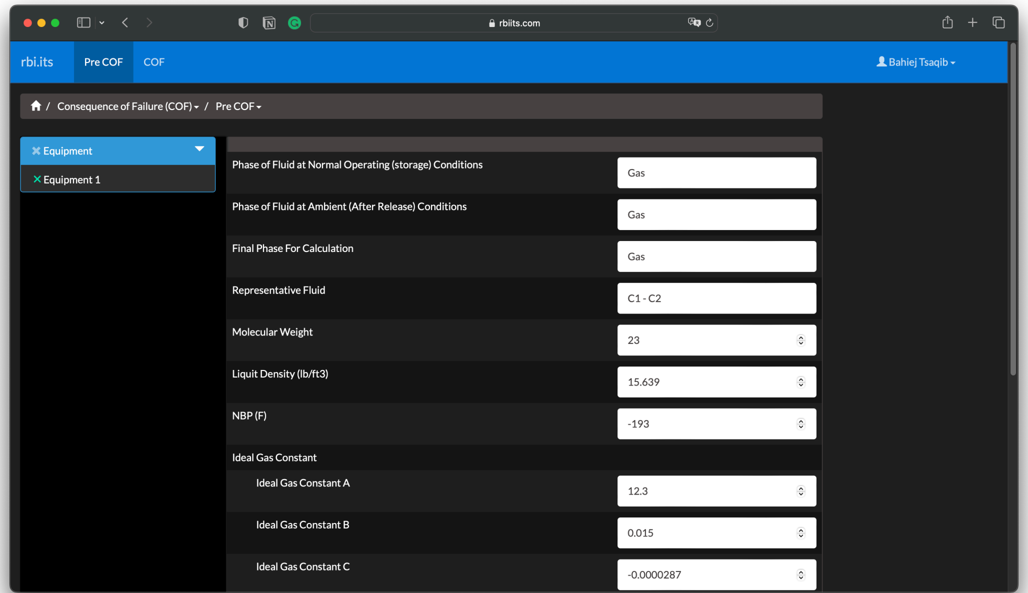

Figure 4. 58 Pre COF Page in Consequence of Failure Menu

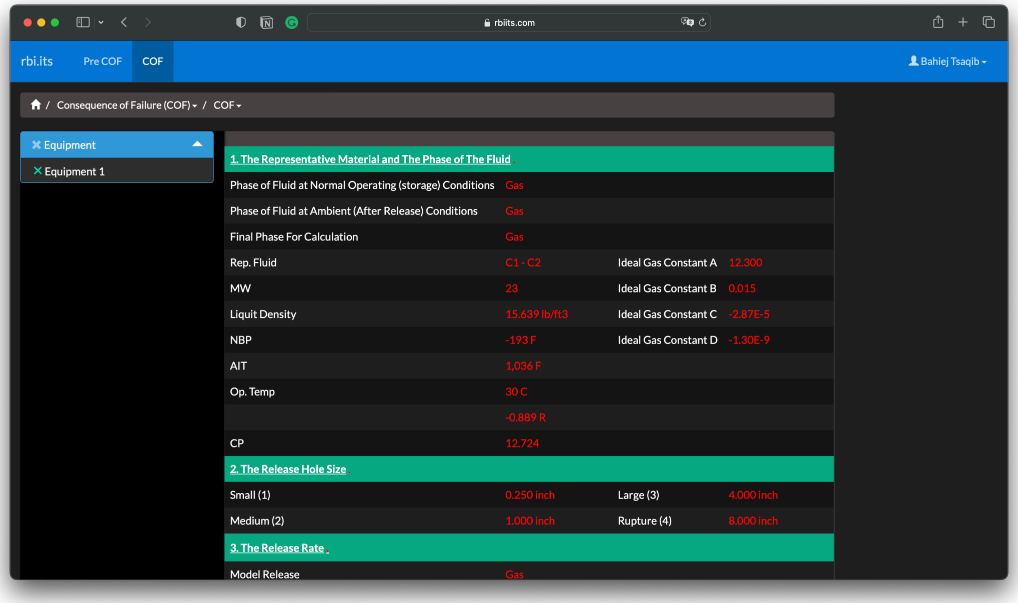

Figure 4. 59 COF Calculation Page in Consequence of Failure Menu

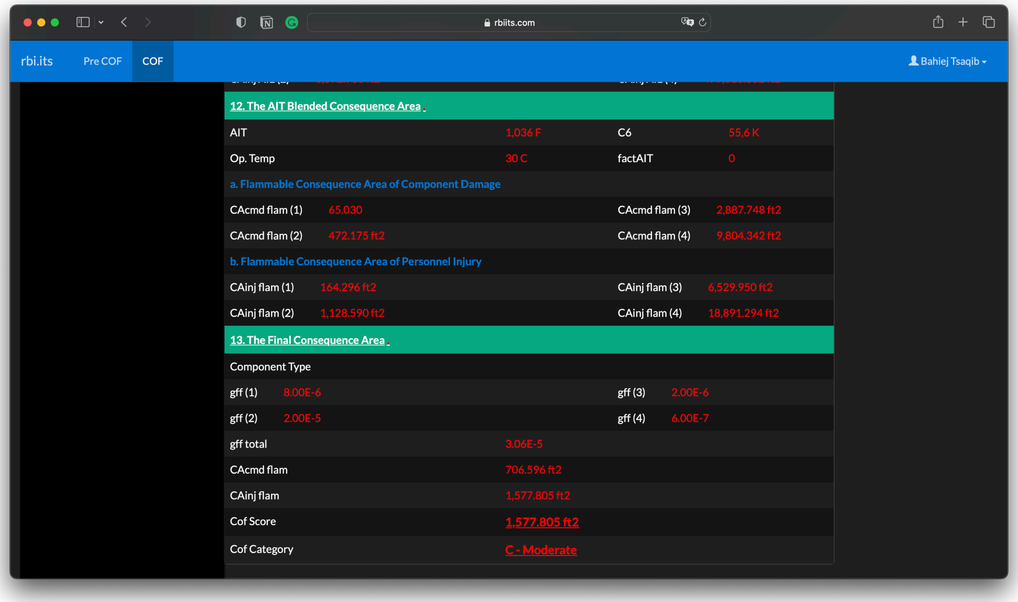

Figure 4. 60 Result of COF Calculation Page in Consequence of Failure Menu

After calculating the probability and consequence of failure and getting the results, then the user can go to the risk analysis menu. In this menu, several summaries of the results of previous calculations are displayed and the system will show the value of the risk score and risk level based on the plotting results of the risk matrix. Risk analysis menu page can be seen in **Figure 4. 42.**

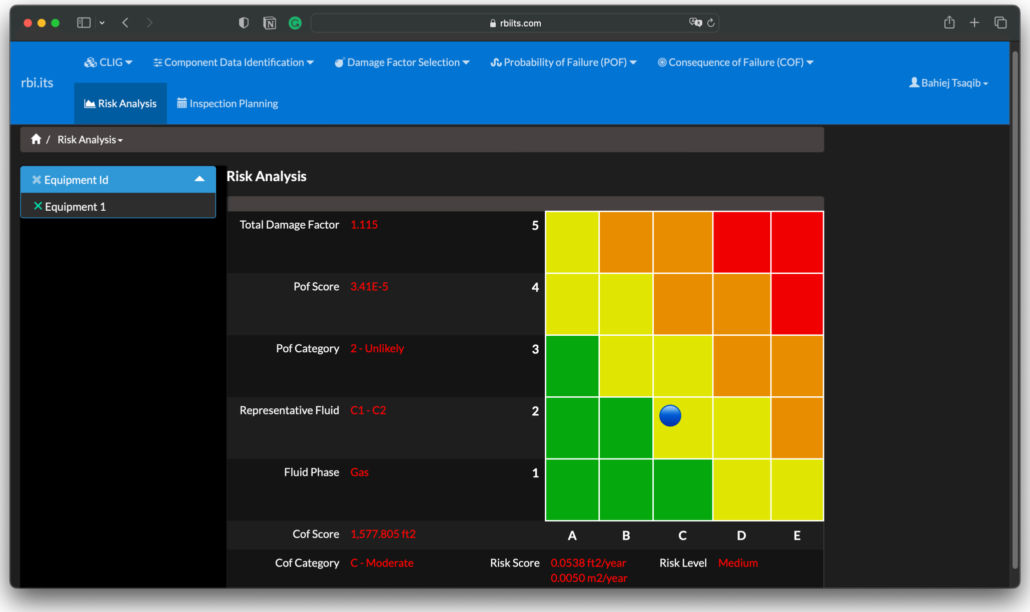

Figure 4. 61 Risk Analysis Menu Page

The last menu in this web application is inspection planning. In this menu, the user first fills in the fields last inspection, last inspection effectiveness, RBI date, and risk target (m^2 / year). After filling in these data fields, the system will automatically provide information related to the next plan date or inspection schedule and inspection recommendations according to each damage factor. Inspection planning menu page can be seen in **Figure 4. 43**.

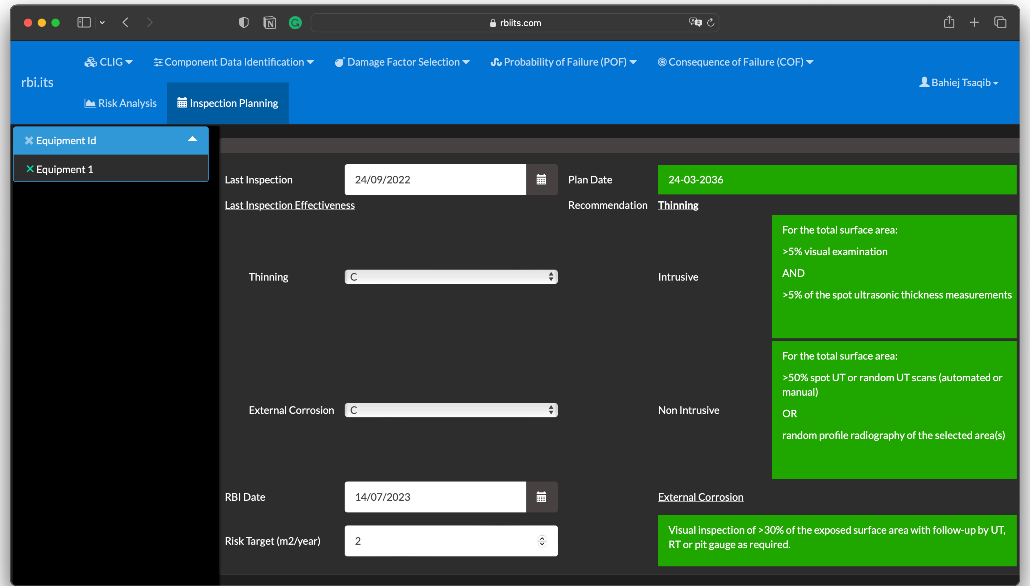

Figure 4. 62 Inspection Planning Menu Page

CHAPTER 5 CONCLUSION

5.1 Conclusion

From the results of the research that has been obtained in this bachelor thesis, several conclusions can be described as follows.

1. Risk-based inspection assessment is carried out on piping with tag number 340-PG-1001-10-06S3 located in the acid gas removal unit at CPF PT X. The result of the probability of failure (POF) calculation is 3,52E-05 with category 2-Unlikely. While the calculation of consequence of failure (COF) is 1577.805 ft^2 with the category C-Moderate.
2. In the risk analysis, a risk score of 0.055 ft^2/year or 0.0055 m^2/year was obtained with a medium risk level category.
3. With a risk target of 2 m^2/year, the piping will be inspected again on 24/03/2036. With the following inspection recommendations.
   A. Thinning
      Intrusive. For the total surface area: >5% visual examination AND >5% of the spot ultrasonic thickness measurements.
      Non-Intrusive. For the total surface area: >50% spot UT or random UT scans (automated or manual) OR random profile radiography of the selected area(s)
   B. External Corrosion
      Visual inspection of >30% of the exposed surface area with follow-up by UT, RT or pit gauge as required.
4. Web application development begins with modeling first. The modeling used is an activity diagram for the display work design and an entity relationship diagram for the database design. After modeling, programming was done with several technologies PHP, MySQL, HTML, CSS. Coding is done in the Visual Studio Code as the text editor application and Laragon is used as the localhost server. Then after programming, the application is run online using web hosting type shared hosting. The web application can be accessed on **https://rbiits.com**. The results of the analysis and calculations obtained in the web application are in accordance with the assessment carried out manually with Microsoft Excel based on API RP 581.

5.2 Recommendation

In the process of this study, there are some drawbacks found on the website application developed. Therefore, there are some recommendations for improvement in further study.

1. The functions in formulas for calculating that are in PHP are not as complete and advanced as microsoft excel. Some functions that do not exist can be searched in some programmer forums although not all of them have been tested.
2. The format of writing and formulating formulas in PHP must also be considered carefully to get the appropriate results in Microsoft Excel and minimize errors.
3. The appearance or interface of the web application can further developed to make it more attractive and convenient to use.

4. RBI web apps can be developed by extending the ability to perform analysis and calculations with more comprehensive consideration.
5. RBI web apps also can be developed by extending the ability to assess not just one type of equipment and component.

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APPENDIX A – RISK BASED INSPECTION METHODOLOGY

1. Thinning Damage Factor

a. Step 1. Determine the furnished thickness
b. Step 2. Determine the corrosion rate for the base material
c. Step 3. Determine the time in-service
d. Step 4. Determine the age of cladding
e. Step 5. Determine t_{min}
f. Step 6. Determine A_{rt} parameter

$$A_{rt} = \frac{C_{r,bm} \cdot age_{tk}}{t_{rdi}}$$

g. Step 7. Calculate the flow stress

$$FS^{\text{Thin}} = \frac{(YS + TS)}{2} \cdot E \cdot 1.1$$

h. Step 8. Calculate the strength ratio parameter

$$SR_P^{\text{Thin}} = \frac{S \cdot E}{FS^{\text{Thin}}} \cdot \frac{\text{Max}(t_{min}, t_c)}{t_{rdi}}$$

i. Step 9. Determine the number of inspections

$$N_A^{\text{Thin}}, N_B^{\text{Thin}}, N_C^{\text{Thin}}, N_D^{\text{Thin}}$$

Table A. 1 Inspection Effectiveness Categories (Source: API RP 581, 2016)

Inspection Effectiveness Category	Inspection Effectiveness Description	Description
A	Highly Effective	The inspection methods will correctly identify the true damage state in nearly every case (or 80-100% confidence).
B	Usually Effective	The inspection methods will correctly identify the true damage state most of the time (or 60-80% confidence).
C	Fairly Effective	The inspection methods will correctly identify the true damage state about half of the time (or 40-60% confidence).
D	Poorly Effective	The inspection methods will provide little information to correctly identify the true damage state (or 20-40% confidence).
E	Ineffective	The inspection method will provide no or almost no information that will correctly identify the true damage state and are considered ineffective for detecting the specific damage mechanism (less than 20% confidence).
Note: On an inspection effectiveness category E, the terminology of ineffective may refer to one or more of the following cases: 1. No inspection was completed. 2. The inspection was completed at less than the requirements stated above. 3. An ineffective inspection technique and/or plan was utilized. 4. An unproven inspection technique was utilized. 5. Insufficient information was available to adequately assess the effectiveness of the inspection.		

j. Step 10. Calculate the inspection effectiveness factors

$$I_1^{\text{Thin}} = \text{Pr}_{p1}^{\text{Thin}} \left(\text{Co}_{p1}^{\text{ThinA}}\right)^{N_A^{\text{Thin}}} \left(C_{p1}^{\text{ThinB } B}\right)^{N_B^{\text{Thin}}} \left(\text{Co}_{p1}^{\text{ThinC } C}\right)^{N_C^{\text{Thin}}} \left(\text{Co}_{p1}^{\text{Thin } D}\right)^{N_D^{\text{Thin}}}$$

$$I_2^{\text{Thin}} = \text{Pr}_{p2}^{\text{Thin}} \left(\text{Co}_{p2}^{\text{ThinA}}\right)^{N_A^{\text{Thin}}} \left(\text{Co}_{p2}^{\text{ThinB } B}\right)^{N_B^{\text{Thin}}} \left(\text{Co}_{p2}^{\text{ThinC } C}\right)^{N_C^{\text{Thin}}} \left(\text{Co}_{p2}^{\text{ThinD}}\right)^{N_D^{\text{Thin}}}$$

$$I_3^{\text{Thin}} = \text{Pr}_{p3}^{\text{Thin}} \left(\text{Co}_{p3}^{\text{ThinA}}\right)^{N_A^{\text{Thin}}} \left(\text{Co}_{p3}^{\text{ThinB } B}\right)^{N_B^{\text{Thin}}} \left(\text{Co}_{p3}^{\text{ThinC}}\right)^{N_C^{\text{Thin}}} \left(\text{Co}_{p3}^{\text{ThinD}}\right)^{N_D^{\text{Thin}}}$$

Table A. 2 Prior Probability for Thinning Corrosion Rate (Source: API RP 581, 2016)

Damage State	Low Confidence Data	Medium Confidence Data	High Confidence Data
Pr_{p1}^{Thin}	0.5	0.7	0.8
Pr_{p2}^{Thin}	0.3	0.2	0.15
Pr_{p3}^{Thin}	0.2	0.1	0.05

Table A. 3 Conditional Probability for Inspection Effectiveness (Source: API RP 581, 2016)

Conditional Probability of Inspection	E – None or Ineffective	D – Poorly Effective	C – Fairly Effective	B – Usually Effective	A – Highly Effective
Co_{p1}^{Thin}	0.33	0.4	0.5	0.7	0.9
Co_{p2}^{Thin}	0.33	0.33	0.3	0.2	0.09
Co_{p3}^{Thin}	0.33	0.27	0.2	0.1	0.01

k. Step 11. Calculate the posterior probabilities

$$Po_{p1}^{\text{Thin}} = \frac{I_1^{\text{Thin}}}{I_1^{\text{Thin}} + I_2^{\text{Thin}} + I_3^{\text{Thin}}}$$

$$Po_{p2}^{\text{Thin}} = \frac{I_2^{\text{Thin}}}{I_1^{\text{Thin}} + I_2^{\text{Thin}} + I_3^{\text{Thin}}}$$

$$Po_{p3}^{\text{Thin}} = \frac{I_3^{\text{Thin}}}{I_1^{\text{Thin}} + I_2^{\text{Thin}} + I_3^{\text{Thin}}}$$

l. Step 12. Calculate the parameters $\beta_1^{\text{Thin}}, \beta_2^{\text{Thin}}, \beta_3^{\text{Thin}}$ assigning $COV_{\Delta t} = 0.20, COV_{S_f} = 0.20$, and $COV_P = 0.05$ where $D_{S_1} = 1, D_{S_2} = 2$ and $D_{S_3} = 4$.

$$\beta_1^{\mathrm{Thin}} = \frac{1 - D_{S_1} \cdot A_{rt} - SR_p^{\mathrm{Thin}}}{\sqrt{D_{S_1}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2 + \left(1 - D_{S_1} \cdot A_{rt}\right)^2 \cdot COV_{S_f}{}^2 + \left(SR_p^{\mathrm{Thin}}\right)^2 \cdot COV_P^2}},$$

$$\beta_2^{\mathrm{Thin}} = \frac{1 - D_{S_2} \cdot A_{rt} - SR_p^{\mathrm{Thin}}}{\sqrt{D_{S_2}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2 + \left(1 - D_{S_2} \cdot A_{rt}\right)^2 \cdot COV_{S_f}{}^2 + \left(SR_p^{\mathrm{Thin}}\right)^2 \cdot COV_P^2}},$$

$$\beta_3^{\mathrm{Thin}} = \frac{1 - D_{S_3} \cdot A_{rt} - SR_p^{\mathrm{Thin}}}{\sqrt{D_{S_3}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2 + \left(1 - D_{S_3} \cdot A_{rt}\right)^2 \cdot COV_{S_f}{}^2 + \left(SR_p^{\mathrm{Thin}}\right)^2 \cdot COV_P^2}}.$$

m. Step 13. Determine the base DF for thinning
n. Step 14. Calculate the base DF for all components

$$D_{fb}^{\mathrm{Thin}} = \left[\frac{\left(Po_{p1}^{\mathrm{Thin}}\,\Phi\left(-\beta_1^{\mathrm{Thin}}\right)\right) + \left(Po_{p2}^{\mathrm{Thin}}\,\Phi\left(-\beta_2^{\mathrm{Thin}}\right)\right) + \left(Po_{p3}^{\mathrm{Thin}}\,\Phi\left(-\beta_3^{\mathrm{Thin}}\right)\right)}{1.56E-04}\right]$$

o. Step 15. Determine the DF for thinning

$$D_f^{\mathrm{Thin}} = max\left[\left(\frac{D_{fB}^{\mathrm{Thin}} \cdot F_{IP} \cdot F_{DL} \cdot F_{WD} \cdot F_{AM} \cdot F_{SM}}{F_{OM}}\right), 0.1\right]$$

2. External Corrosion Damage Factor

a. Step 1. Determine the furnished thickness and the age for the component from the installation
b. Step 2. Determine the base corrosion rate
   Corrosion Rates for Calculation of the Damage Factor – External Corrosion

Table A. 4 Corrosion Rates of the Damage Factor – External Corrosion (Source: API RP 581, 2016)

Operating Temperature (°C)	Corrosion Rate as a Function of Driver (1) (mm/y)			
	Marine / Cooling Tower Drift Area	Temperate	Arid / Dry	Severe
-12	0	0	0	0
-8	0.025	0	0	0
6	0.127	0.076	0.025	0.254
32	0.127	0.076	0.025	0.254
71	0.127	0.051	0.025	0.254
107	0.025	0	0	0.051
121	0	0	0	0

Note:
1. Driver is defined as the atmospheric condition causing the corrosion rate.
2. Interpolation may be used for intermediate values of temperature.
3. A time-weighted average corrosion rate may be used for systems that are in intermittent service or that operate at 2 or more temperatures.

c. Step 3. Determine the final corrosion rate

$$C_r = C_{rB} \cdot max\left[F_{EQ}, F_{IF}\right]$$

Adjustment for Equipment Design or Fabrication, FEQ – If the equipment has a design which allows water to pool and increase metal loss rates, such as piping supported directly on beams, vessel stiffening rings or insulation supports or other such configuration that does not allow water egress and/or does not allow for proper coating maintenance, then FE Q = 2; otherwise, FEQ = 1.

Adjustment for Interface, FIF – If the piping has an interface where it enters either soil or water, then F =2;otherwise, F =1

d. Step 4. Determine the time in-service since the last inspection
e. Step 5. Determine the in-service time since the coating has been installed

$$\text{age}_{\text{coat}} = \text{Calculation Date} - \text{Coating Installation Date}$$

f. Step 6. Determine coating adjustment

If $age_{tk} \geq age_{\text{coat}}$:

$$\text{Coat}_{adj} = 0$$
$$\text{Coat}_{adj} = min[5,\ \text{age}_{\text{coat}}]$$
$$\text{Coat}_{adj} = min[15,\ \text{age}_{\text{coat}}]$$

If $age_{tk} < age_{\text{coat}}$:

$$\text{Coat}_{adj} = 0$$
$$\text{Coat}_{adj} = min[5,\ \text{age}_{\text{coat}}] - min[5, \text{age } e_{\text{coat}} - age_{tk}]$$
$$\text{Coat}_{adj} = min[15,\ \text{age}_{\text{coat}}] - min[15, \text{age } e_{\text{coat}} - age_{tk}]$$

g. Step 7. Determine the in-service time over which external corrosion may have occurred

$$\text{age} = \text{age}_{\text{tk}} - \text{Coat}_{adj}$$

h. Step 8. Determine the allowable stress, weld joint efficiency, and minimum required thickness
i. Step 9. Determine A_{rt} parameter

$$A_{rt} = \frac{C_r \cdot age}{t_{rde}}$$

j. Step 10. Calculate the flow stress

$$FS^{\text{extcorr}} = \frac{(YS + TS)}{2} \cdot E \cdot 1.1$$

k. Step 11. Calculate the strength ratio parameter

$$SR_P^{\text{extcorr}} = \frac{S \cdot E}{FS^{\text{extcorr}}} \cdot \frac{\text{Max}(t_{min}, t_c)}{t_{rde}}$$

l. Step 12. Determine the number of inspections $N_A^{\text{extcorr}}, N_B^{\text{extcorr}}, N_C^{\text{extcorr}}, N_D^{\text{extcorr}}$
m. Step 13. Calculate the inspection effectiveness factors
See **Table A. 2** and **Table A. 3** to determine prior and conditional probability.

$$I_1^{\text{extcorr}} = P_{p1}^{\text{extcorr}} \left(Co_{p1}^{\text{extcorrA } A}\right)^{N_A^{\text{extoor}}} \left(Co_{p1}^{\text{extcorrB } B}\right)^{N_B^{\text{extoorr}}} \left(Co_{p1}^{\text{extcorr } C}\right)^{N_C^{\text{extoor}}} \left(Co_{p1}^{\text{extcorr } D}\right)^{N_D^{\text{extoor}}}$$
$$I_2^{\text{extcorr}} = \text{Pr}_{p2}^{\text{extcorr}} \left(Co_{p2}^{\text{extcorrA } A}\right)^{N_A^{\text{extoorr}}} \left(\text{Co}_{p2}^{\text{extcorrB}}\right)^{N_B^{\text{extoorr}}} \left(\text{Co}_{p2}^{\text{extcorr } C}\right)^{N_C^{\text{extcorr}}} \left(\text{Co}_{p2}^{\text{extcorrD}}\right)^{N_D^{\text{extoor}}}$$
$$I_3^{\text{extcorr}} = \text{Pr}_{p3}^{\text{extcorr}} \left(\text{Co}_{p3}^{\text{extcorrA}}\right)^{N_A^{\text{extoor}}} \left(\text{Co}_{p3}^{\text{extcorrB}}\right)^{N_B^{\text{extoor}}} \left(\text{Co}_{p3}^{\text{extcorrC}}\right)^{N_C^{\text{extoor}}} \left(\text{Co}_{p3}^{\text{extcorrD}}\right)^{N_D^{\text{extoor}}}$$

n. Step 14. Calculate the posterior probabilities $Po_{p1}^{\text{extcorr}}, Po_{p2}^{\text{extcorr}}$ and Po_{p3}^{extcorr}

$$Po_{p1}^{\text{extcorr}} = \frac{I_1^{\text{extcorr}}}{I_1^{\text{extcorr}} + I_2^{\text{extcorr}} + I_3^{\text{extcorr}}}$$

$$Po_{p2}^{\text{extcorr}} = \frac{I_2^{\text{extcorr}}}{I_1^{\text{extcorr}} + I_2^{\text{extcorr}} + I_3^{\text{extcorr}}}$$

$$Po_{p3}^{\text{extcorr}} = \frac{I_3^{\text{extcorr}}}{I_1^{\text{extcorr}} + I_2^{\text{extcorr}} + I_3^{\text{extcorr}}}$$

o. Step 15. Calculate the parameters $\beta_1^{\text{Thin}}, \beta_2^{\text{Thin}}, \beta_3^{\text{Thin}}$ assigning $COV_{\Delta t} = 0.20, COV_{S_f} = 0.20$ and $COV_P = 0.05$. where $D_{S_1} = 1, D_{S_2} = 2$ and $D_{S_3} = 4$

$$\beta_1^{\text{extcorr}} = \frac{1 - D_{S_1} \cdot A_{rt} - SR_p^{\text{extcorr}}}{\sqrt{D_{S_1}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2 + \left(1 - D_{S_1} \cdot A_{rt}\right)^2 \cdot COV_{S_f}{}^2 + \left(SR_p^{\text{extcorr}}\right)^2 \cdot COV_P{}^2}},$$

$$\beta_2^{\text{extcorr}} = \frac{1 - D_{S_2} \cdot A_{rt} - SR_p^{\text{extcorr}}}{\sqrt{D_{S_2}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2 + \left(1 - D_{S_2} \cdot A_{rt}\right)^2 \cdot COV_{S_f}{}^2 + \left(SR_p^{\text{extcorr}}\right)^2 \cdot COV_P{}^2}},$$

$$\beta_3^{\text{extcorr}} = \frac{1 - D_{S_3} \cdot A_{rt} - SR_p^{\text{extcorr}}}{\sqrt{D_{S_3}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2 + \left(1 - D_{S_3} \cdot A_{rt}\right)^2 \cdot COV_{S_f}{}^2 + \left(SR_p^{\text{extcorr}}\right)^2 \cdot COV_P{}^2}}.$$

p. Step 16. Determine the DF for external corrosion

$$D_f^{\text{extcorr}} = \left[\frac{\left(Po_{p1}^{\text{extcorr}}\,\Phi(-\beta_1^{\text{extcorr}})\right) + \left(Po_{p2}^{\text{extcorr}}\,\Phi(-\beta_2^{\text{extcorr}})\right) + \left(Po_{p3}^{\text{extcorr}}\,\Phi(-\beta_3^{\text{extcorr}})\right)}{1.56E - 04}\right]$$

3. Consequence of Failure

1. Determine the Representative Fluid and Associated Properties

Table A. 5 Guidelines for Determining the Phase of a Fluid (Source: API RP 581, 2016)

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (after release) Conditions	Determination of Final Phase for Consequence Calculation
Gas	Gas	model as gas
Gas	Liquid	model as gas
Liquid	Gas	model as gas *unless* the fluid boiling point at ambient conditions is greater than 80°F, then model as a liquid
Liquid	Liquid	model as liquid

Step 1. Select a representative fluid group
Step 2. Determine the stored fluid phase
Step 3. Determine the stored fluid properties
Step 4. Determine the steady state phase of the fluid after release to the atm

2. Release Hole Size Selection

Step 1. Determine the release hole size diameter

Table A. 6 Release Hole Sizes and Areas in Level 1 and 2 Consequences Analysis (Source: API RP 581, 2016)

Release Hole Number	Release Hole Size	Range of Hole Diameters (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 – ¼	$d_1 = 0.25$
2	Medium	> ¼ – 2	$d_2 = 1$
3	Large	> 2 – 6	$d_3 = 4$
4	Rupture	> 6	$d_4 = \min[D, 16]$

Step 2. Determine the generic failure frequency

3. Release Rate Calculation

Step 1. Determine the fluid phase
Step 2. Calculate the release hole size area

$$A_n = \frac{\pi d_n^2}{4}$$

Step 3. Viscosity correction factor
Step 4. Calculate the release rate for each release area

$$W_n = \frac{C_d}{C_2} \cdot A_n \cdot P_s \sqrt{\left(\frac{k \cdot MW \cdot g_c}{R \cdot T_s}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

4. **Estimate the Fluid Inventory Available for Release**
   Step 1. Group comp. and eq. items into inventory groups
   Step 2. Determine the fluid mass
   Step 3. Determine the fluid mass in each of the other components in the inventory group
   Step 4. Determine the fluid mass in the inventory group
   Step 5. Calculate the flow rate a 203 mm (8 in) diameter hole
   Step 6. For each release hole size, calculate the added fluid mass
   Step 7. For each release hole size, calculate the available mass
5. **Determine the Release Type (Continuous or Instantaneous)**
   Step 1. Calculate the time required to release 4,536 kg
   Step 2. Determine release type is instantaneous or continuous
6. **Assess the Impact of Detection and Isolation Systems**

   Step 1. Detection and isolation systems present in the unit

Table A. 7 Detection and Isolation System Rating Guide (Source: API RP 581, 2016)

Type of Detection System	Detection Classification
Instrumentation designed specifically to detect material losses by changes in operating conditions (i.e., loss of pressure or flow) in the system.	A
Suitably located detectors to determine when the material is present outside the pressure-containing envelope.	B
Visual detection, cameras, or detectors with marginal coverage.	C
Type of Isolation System	**Isolation Classification**
Isolation or shutdown systems activated directly from process instrumentation or detectors, with no operator intervention.	A
Isolation or shutdown systems activated by operators in the control room or other suitable locations remote from the leak.	B
Isolation dependent on manually-operated valves.	C

Step 2. The release reduction factor

Table A. 8 Adjustments to Release Based on Detection and Isolation Systems (Source: API RP 581, 2016)

System Classifications		Release Magnitude Adjustment	Reduction Factor, $fact_{di}$
Detection	Isolation		
A	A	Reduce release rate or mass by 25%	0.25
A	B	Reduce release rate or mass by 20%	0.20
A or B	C	Reduce release rate or mass by 10%	0.10
B	B	Reduce release rate or mass by 15%	0.15
C	C	No adjustment to release rate or mass	0.00

Step 3. The total leak durations

7. Determine the Release Rate and Mass for COF

Step 1. Calculate the adjusted release rate
Step 2. Calculate the leak duration

Table A. 9 Leak Duration Based on Detection Systems
(Source: API RP 581, 2016)

Detection System Rating	Isolation System Rating	Maximum Leak Duration, ld_{max}
A	A	20 minutes for 1/4 inch leaks 10 minutes for 1 inch leaks 5 minutes for 4 inch leaks
A	B	30 minutes for 1/4 inch leaks 20 minutes for 1 inch leaks 10 minutes for 4 inch leaks
A	C	40 minutes for 1/4 inch leaks 30 minutes for 1 inch leaks 20 minutes for 4 inch leaks
B	A or B	40 minutes for 1/4 inch leaks 30 minutes for 1 inch leaks 20 minutes for 4 inch leaks
B	C	1 hour for 1/4 inch leaks 30 minutes for 1 inch leaks 20 minutes for 4 inch leaks
C	A, B or C	1 hour for 1/4 inch leaks 40 minutes for 1 inch leaks 20 minutes for 4 inch leaks

Step 3. Calculate the release mass

8. Determine Flammable and Explosive Consequence

Step 1. Select the consequence area mitigation reduction factor
Step 2. Calculate the energy efficiency correction factor
Step 3. Determine the fluid type

A. Component Damage

Table A. 10 Component Damage Flammable Consequence Equation (Source: API RP 581, 2016)

Fluid	Continuous Releases Constants								Instantaneous Releases Constants							
	Auto-Ignition Not Likely (CAINL)				Auto-Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto-Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
C_1-C_2	43.0	0.98			280.0	0.95			41.0	0.67			1079	0.62		
C_3-C_4	49.48	1.00			313.6	1.00			27.96	0.72			522.9	0.63		
C_5	25.17	0.99	536.0	0.89	304.7	1.00			13.38	0.73	1.49	0.85	275.0	0.61		
C_6-C_8	29.0	0.98	182.0	0.89	312.4	1.00	525.0	0.95	13.98	0.66	4.35	0.78	275.7	0.61	57.0	0.55
C_9-C_{12}	12.0	0.98	130.0	0.90	391.0	0.95	560.0	0.95	7.1	0.66	3.3	0.76	281.0	0.61	6.0	0.53
C_{13}-C_{16}			64.0	0.90			1023	0.92			0.46	0.88			9.2	0.88
C_{17}-C_{25}			20.0	0.90			861.0	0.92			0.11	0.91			5.6	0.91
C_{25} +			11.0	0.91			544.0	0.90			0.03	0.99			1.4	0.99
H_2	64.5	0.992			420.0	1.00			61.5	0.657			1430	0.618		
H_2S	32.0	1.00			203.0	0.89			148.0	0.63			357.0	0.61		
HF																
Aromatics	17.87	1.097	103.0	1.00	374.5	1.055			11.46	0.667	70.12	1.00	512.6	0.713	701.2	1.00
Styrene	17.87	1.097	103.0	1.00	374.5	1.055			11.46	0.667	70.12	1.00	512.6	0.713	701.2	1.00
CO	0.107	1.752							69.68	0.667						
DEE	39.84	1.134	737.4	1.106	320.7	1.033	6289	0.649	155.7	0.667	5.105	0.919			5.672	0.919
Methanol	0.026	0.909	1751	0.934					28.11	0.667	1.919	0.900				
PO	14.62	1.114	1295	0.960					65.58	0.667	3.404	0.869				
EEA	0.002	1.035	117.0	1.00					8.014	0.667	69.0	1.00				
EE	12.62	1.005	173.1	1.00					38.87	0.667	72.21	1.00				
EG	7.721	0.973	108.0	1.00					6.525	0.667	69.0	1.00				
EO	31.03	1.069							136.3	0.667						
Pyrophoric	12.0	0.98	130.0	0.90	391.0	0.95	560.0	0.95	7.1	0.66	3.3	0.76	281.0	0.61	6.0	0.53

B. Personnel Injury

Table A. 11 Personnel Injury Flammable Consequence Equation Constants (Source: API RP 581, 2016

Fluid	Continuous Releases Constants								Instantaneous Releases Constants							
	Auto-Ignition Not Likely (CAINL)				Auto-Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto-Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
C_1-C_2	110.0	0.96			745.0	0.92			79.0	0.67			3100	0.63		
C_3-C_4	125.2	1.00			836.7	1.00			57.72	0.75			1769	0.63		
C_5	62.05	1.00	1545	0.89	811.0	1.00			28.45	0.76	4.34	0.85	959.6	0.63		
C_6-C_8	68.0	0.96	516.0	0.89	828.7	1.00	1315	0.92	26.72	0.67	12.7	0.78	962.8	0.63	224.0	0.54
C_9-C_{12}	29.0	0.96	373.0	0.89	981.0	0.92	1401	0.92	13.0	0.66	9.5	0.76	988.0	0.63	20.0	0.54
C_{13}-C_{16}			183.0	0.89			2850	0.90			1.3	0.88			26.0	0.88
C_{17}-C_{25}			57.0	0.89			2420	0.90			0.32	0.91			16.0	0.91
C_{25} +			33.0	0.89			1604	0.90			0.081	0.99			4.1	0.99
H_2	165.0	0.933			1117	1.00			118.5	0.652			4193	0.621		
H_2S	52.0	1.00			375.0	0.94			271.0	0.63			1253	0.63		
HF																
Aromatics	64.14	0.963	353.5	0.883	1344	0.937	487.7	0.268	18.08	0.686	0.14	0.935	512.6	0.713	1.404	0.935
Styrene	64.14	0.963	353.5	0.883	1344	0.937	487.7	0.268	18.08	0.686	0.14	0.935	512.6	0.713	1.404	0.935
CO	27.0	0.991							105.3	0.692						
DEE	128.1	1.025	971.9	1.219	1182	0.997	2658	0.864	199.1	0.682	47.13	0.814	821.7	0.657	52.36	0.814
Methanol	0.016	1.008	4484	0.902					37.71	0.688	6.255	0.871				
PO	38.76	1.047	1955	0.840					83.68	0.682	15.21	0.834				
EEA	0.017	0.946	443.1	0.835					11.41	0.687	0.153	0.924				
EE	35.56	0.969	46.56	0.800					162.0	0.660	0.152	0.927				
EG	25.67	0.947	324.7	0.869					8.971	0.687	0.138	0.922				
EO	49.43	1.105							220.8	0.665						
Pyrophoric	29.0	0.96	373.0	0.89	981.0	0.92	1401	0.92	13.0	0.66	9.5	0.76	988.0	0.63	20.0	0.54

Step 4. The component damage consequence areas for Autoignition Not Likely - Continuous Release

Step 5. The component damage consequence areas for Autoignition Likely - Continuous Release

Step 6. The component damage consequence areas for Autoignition Not Likely - Instantaneous Release

Step 7. The component damage consequence areas for Autoignition Likely - Instantaneous Release

Step 8. The personnel injury consequence areas for Autoignition Not Likely - Continuous Release

Step 9. The personnel injury consequence areas for Autoignition Likely - Continuous Release

Step 10. The personnel injury consequence areas for Autoignition Not Likely - Instantaneous Release

Step 11. The personnel injury consequence areas for Autoignition Likely - Instantaneous Release
Step 12. Calculate the instantaneous/continuous blending factor
Step 13. Calculate the AIT blending factor, $fact^{AIT}$
Step 14. Calculate the continuous / instantaneous blended consequence areas (Type 0)
Step 15. Calculate the AIT blended consequence areas

Table A. 12 Adjustments to Flammable Consequence for Mitigation Systems (Source: API RP 581, 2016)

Mitigation System	Consequence Area Adjustment	Consequence Area Reduction Factor, $fact_{mit}$
Inventory blowdown, coupled with isolation system classification B or higher	Reduce consequence area by 25%	0.25
Fire water deluge system and monitors	Reduce consequence area by 20%	0.20
Fire water monitors only	Reduce consequence area by 5%	0.05
Foam spray system	Reduce consequence area by 15%	0.15

Step 16. Determine the final consequence areas

9. Determine Toxic Consequence
10. Determine Nonflammable, Nontoxic Consequence
11. Determine the Final Consequence Area

Step 1. Calculate the final component damage consequence area
Step 2. Calculate the final personnel injury consequence area
Step 3. Final Consequence Area

APPENDIX B – ASSET DATA AND INFORMATION

1. Asset

Line/Tag Number	340-PG-1001-10-06S3
Type	Pipe 10"
Material	Carbon Steel ASTM A106 Gr B
Fluid Handle	C1-C2
From	Acid Gas Absorber (340-T-1001)
To	Sweet Gas KO Drum (340-D-1002)
Unit	AGRU - SRU
P&ID No.	MTDF-PR-340-PID-1002 MTDF-PR-340-PID-1009

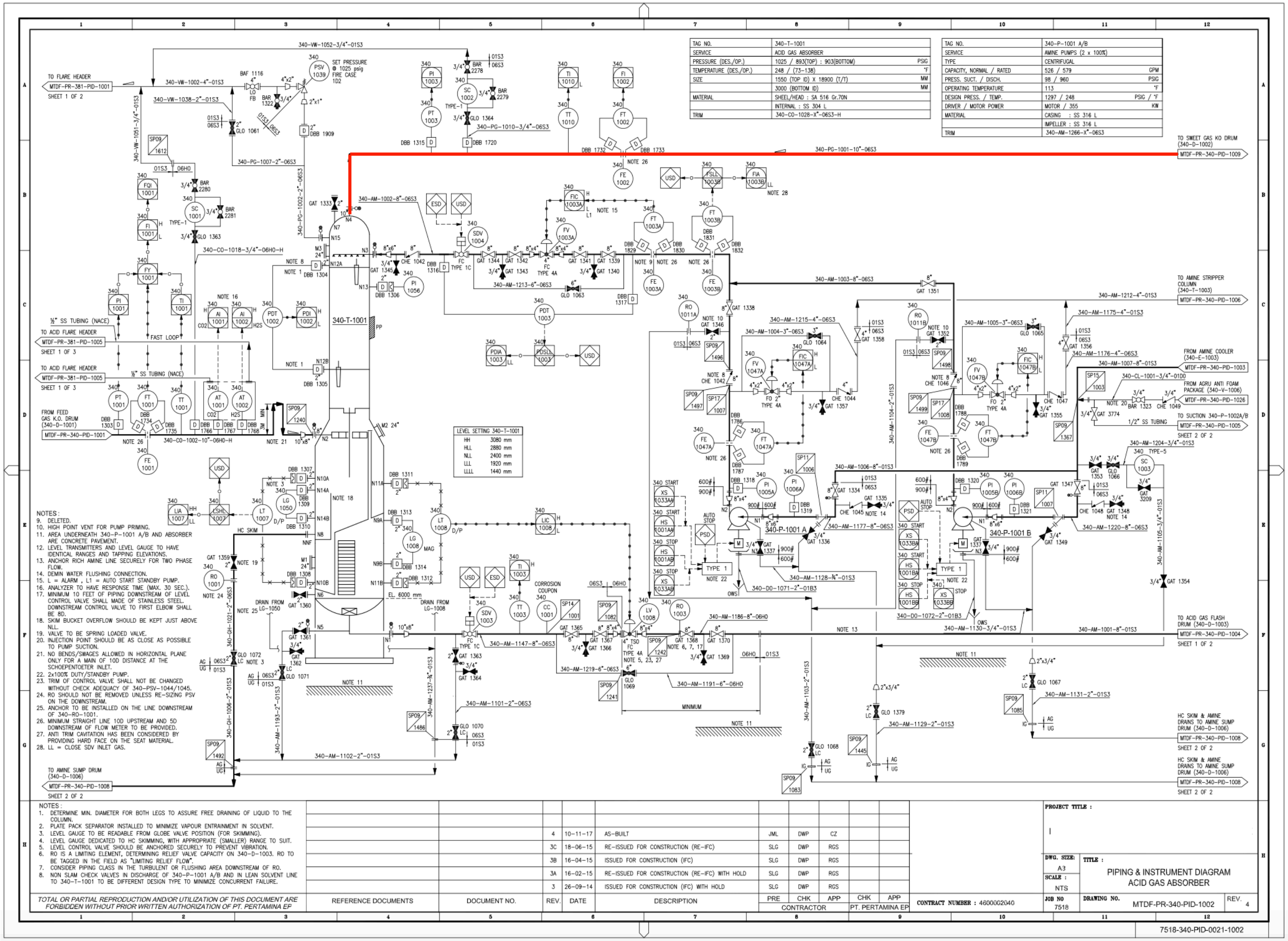
2. General Properties

Material of Construction	Carbon or Low Alloy
Lining Present	Yes
Insulation Present	No
Exposed to Chloride and Water	Yes
Operating Temperature (°C)	30
Operating Pressure (MPa)	6,16
Date of Installation	09/03/17

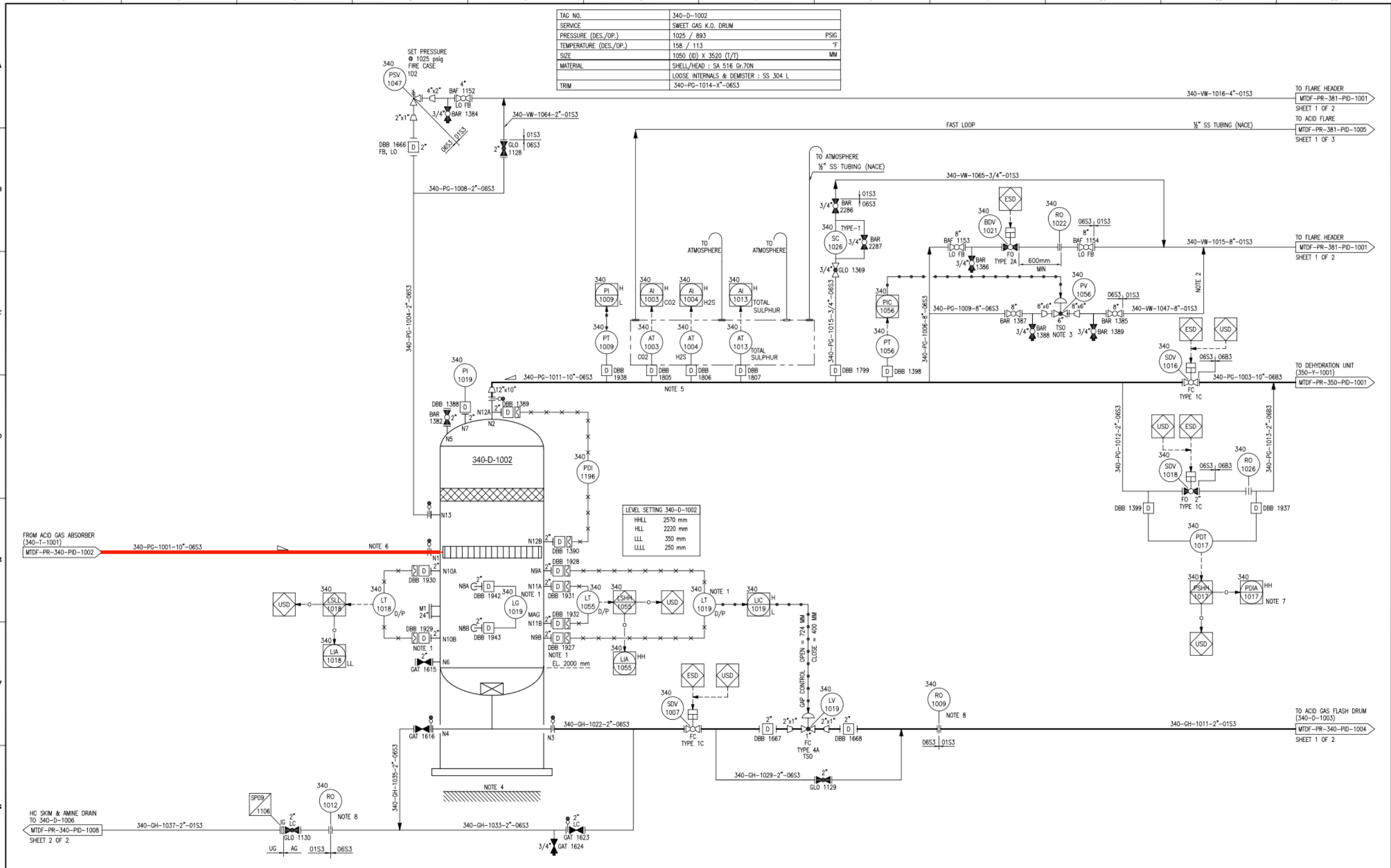
3. Component Data

Starting Date	09/03/17
Last Inspection	24/09/22
Thickness (mm)	14,15
Corrosion Allowance (in)	0,118
Max. Design Temperature (°C)	204,4
Min. Design Temperature (°C)	-28,9
Max. Design Pressure (MPa)	10,2
Operating Temperature (°C)	30
Operating Pressure (MPa)	6,16
Design Code	ASME B31.3
Equipment Type	Pipe
Component Type	PIPE - 10
Diameter (in)	10
Component Geometry Data	CYL, ELB
Material Specification	ASTM A106 Gr B
Yield Strength (MPa)	240
Tensile Strength (MPa)	415
Allowable Stress (MPa)	138
Weld Joint Efficiency	1
Heat Tracing	No

APPENDIX C – PIPING AND INSTRUMENTATION DIAGRAM



TAG NO. | 340-T-1001
SERVICE | ACID GAS ABSORBER
PRESSURE (DES./OP.) | 1025 / 893(TOP) : 903(BOTTOM) PSIG
TEMPERATURE (DES./OP.) | 248 / (73-138) °F
SIZE | 1550 (TOP ID) X 18900 (T/T) MM
3000 (BOTTOM ID) MM
MATERIAL | SHEEL/HEAD : SA 516 Gr.70N
INTERNAL : SS 304 L
TRIM | 340-CO-1028-X"-06S3-H
TAG NO. | 340-P-1001 A/B
SERVICE | AMINE PUMPS (2 x 100%)
TYPE | CENTRIFUGAL
CAPACITY, NORMAL / RATED | 526 / 579 GPM
PRESS. SUCT. / DISCH. | 98 / 960 PSIG
OPERATING TEMPERATURE | 113 °F
DESIGN PRESS. / TEMP. | 1297 / 248 PSIG / °F
DRIVER / MOTOR POWER | MOTOR / 355 KW
MATERIAL | CASING : SS 316 L
IMPELLER : SS 316 L
TRIM | 340-AM-1266-X"-06S3
340-PG-1001-10"-06S3
TO SWEET GAS KO DRUM (340-D-1002)
MTDF-PR-340-PID-1009
340-T-1001
340-P-1001 A
340-P-1001 B
NOTES :
9. DELETED.
10. HIGH POINT VENT FOR PUMP PRIMING.
11. AREA UNDERNEATH 340-P-1001 A/B AND ABSORBER ARE CONCRETE PAVEMENT.
12. LEVEL TRANSMITTERS AND LEVEL GAUGE TO HAVE IDENTICAL RANGES AND TAPPING ELEVATIONS.
13. ANCHOR RICH AMINE LINE SECURELY FOR TWO PHASE FLOW.
14. DEMIN WATER FLUSHING CONNECTION.
15. L = ALARM , L1 = AUTO START STANDBY PUMP.
16. ANALYZER TO HAVE RESPONSE TIME (MAX. 30 SEC.).
17. MINIMUM 10 FEET OF PIPING DOWNSTREAM OF LEVEL CONTROL VALVE SHALL MADE OF STAINLESS STEEL. DOWNSTREAM CONTROL VALVE TO FIRST ELBOW SHALL BE 8D.
18. SKIM BUCKET OVERFLOW SHOULD BE KEPT JUST ABOVE NLL.
19. VALVE TO BE SPRING LOADED VALVE.
20. INJECTION POINT SHOULD BE AS CLOSE AS POSSIBLE TO PUMP SUCTION.
21. NO BENDS/SWAGES ALLOWED IN HORIZONTAL PLANE ONLY FOR A MAIN OF 10D DISTANCE AT THE SCHOEPENTOETER INLET.
22. 2x100% DUTY/STANDBY PUMP.
23. TRIM OF CONTROL VALVE SHALL NOT BE CHANGED WITHOUT CHECK ADEQUACY OF 340-PSV-1044/1045.
24. RO SHOULD NOT BE REMOVED UNLESS RE-SIZING PSV ON THE DOWNSTREAM.
25. ANCHOR TO BE INSTALLED ON THE LINE DOWNSTREAM OF 340-RO-1001.
26. MINIMUM STRAIGHT LINE 10D UPSTREAM AND 5D DOWNSTREAM OF FLOW METER TO BE PROVIDED.
27. ANTI TRIM CAVITATION HAS BEEN CONSIDERED BY PROVIDING HARD FACE ON THE SEAT MATERIAL.
28. LL = CLOSE SDV INLET GAS.
NOTES :
1. DETERMINE MIN. DIAMETER FOR BOTH LEGS TO ASSURE FREE DRAINING OF LIQUID TO THE COLUMN.
2. PLATE PACK SEPARATOR INSTALLED TO MINIMIZE VAPOUR ENTRAINMENT IN SOLVENT.
3. LEVEL GAUGE TO BE READABLE FROM GLOBE VALVE POSITION (FOR SKIMMING).
4. LEVEL GAUGE DEDICATED TO HC SKIMMING, WITH APPROPRIATE (SMALLER) RANGE TO SUIT.
5. LEVEL CONTROL VALVE SHOULD BE ANCHORED SECURELY TO PREVENT VIBRATION.
6. RO IS A LIMITING ELEMENT, DETERMINING RELIEF VALVE CAPACITY ON 340-D-1003. RO TO BE TAGGED IN THE FIELD AS "LIMITING RELIEF FLOW".
7. CONSIDER PIPING CLASS IN THE TURBULENT OR FLUSHING AREA DOWNSTREAM OF RO.
8. NON SLAM CHECK VALVES IN DISCHARGE OF 340-P-1001 A/B AND IN LEAN SOLVENT LINE TO 340-T-1001 TO BE DIFFERENT DESIGN TYPE TO MINIMIZE CONCURRENT FAILURE.
TOTAL OR PARTIAL REPRODUCTION AND/OR UTILIZATION OF THIS DOCUMENT ARE FORBIDDEN WITHOUT PRIOR WRITTEN AUTHORIZATION OF PT. PERTAMINA EP
4 | 10-11-17 | AS-BUILT | JML | DWP | CZ
3C | 18-06-15 | RE-ISSUED FOR CONSTRUCTION (RE-IFC) | SLG | DWP | RGS
3B | 16-04-15 | ISSUED FOR CONSTRUCTION (IFC) | SLG | DWP | RGS
3A | 16-02-15 | RE-ISSUED FOR CONSTRUCTION (RE-IFC) WITH HOLD | SLG | DWP | RGS
3 | 26-09-14 | ISSUED FOR CONSTRUCTION (IFC) WITH HOLD | SLG | DWP | RGS
REFERENCE DOCUMENTS | DOCUMENT NO. | REV. | DATE | DESCRIPTION | PRE | CHK | APP | CHK | APP
CONTRACTOR | PT. PERTAMINA EP
CONTRACT NUMBER : 4600002040
PROJECT TITLE :
DWG. SIZE: A3
SCALE : NTS
TITLE : PIPING & INSTRUMENT DIAGRAM ACID GAS ABSORBER
JOB NO 7518
DRAWING NO. MTDF-PR-340-PID-1002
REV. 4
7518-340-PID-0021-1002



TAG NO.	340-D-1002	
SERVICE	SWEET GAS K.O. DRUM	
PRESSURE (DES./OP.)	1025 / 893	PSIG
TEMPERATURE (DES./OP.)	158 / 113	°F
SIZE	1050 (ID) X 3520 (T/T)	MM
MATERIAL	SHELL/HEAD : SA 516 Gr.70N	
	LOOSE INTERNALS & DEMISTER : SS 304 L	
TRIM	340-PG-1014-X"-06S3	

LEVEL SETTING 340-D-1002	
HHLL	2570 mm
HLL	2220 mm
LLL	350 mm
LLLL	250 mm

NOTES :
1. LEVEL TRANSMITTERS AND LEVEL GAUGE TO HAVE IDENTICAL RANGES AND TAPPING ELEVATIONS.
2. START-UP VENT.
3. PROVIDE ALARM IN DCS IF VALVE IS NOT FULLY CLOSED.
4. VESSEL AREA IS CONCRETE PAVEMENT.
5. ANALYZER TO HAVE SHORT RESPONSE TIME (MAX. 30 SECONDS).
6. NO BENDS/SWAGES ALLOWED IN HORIZONTAL PLANE ONLY FOR A MAIN OF 10D DISTANCE AT THE SCHOEPENTOETER INLET.
7. 340-PDAHH-1017 INHIBITS 340-SDV-1016 OPENING ON HIGH PRESSURE DIFFERENTIAL HIGHER THAN 20 PSIG. 340-SDV-1018 IS CLOSED AUTOMATICALLY ONCE 340-SDV-1016 OPENS.
8. RO SHOULD NOT BE REMOVED UNLESS RE-SIZING PSV ON THE DOWNSTREAM.

REFERENCE DOCUMENTS	DOCUMENT NO.	REV.	DATE	DESCRIPTION	PRE (CONTRACTOR)	CHK (CONTRACTOR)	APP (CONTRACTOR)	CHK (PT. PERTAMINA EP)	APP (PT. PERTAMINA EP)
		4	10-11-17	AS-BUILT	JML	DWP	CZ		
		3C	18-06-15	RE-ISSUED FOR CONSTRUCTION (RE-IFC)	SLG	DWP	RGS		
		3B	16-04-15	ISSUED FOR CONSTRUCTION (IFC)	SLG	DWP	RGS		
		3A	16-02-15	RE-ISSUED FOR CONSTRUCTION (RE-IFC) WITH HOLD	SLG	DWP	RGS		
		3	26-09-14	ISSUED FOR CONSTRUCTION (IFC) WITH HOLD	SLG	DWP	RGS		

CONTRACT NUMBER : 4600002040

PROJECT TITLE :

DWG. SIZE: A3

SCALE : NTS

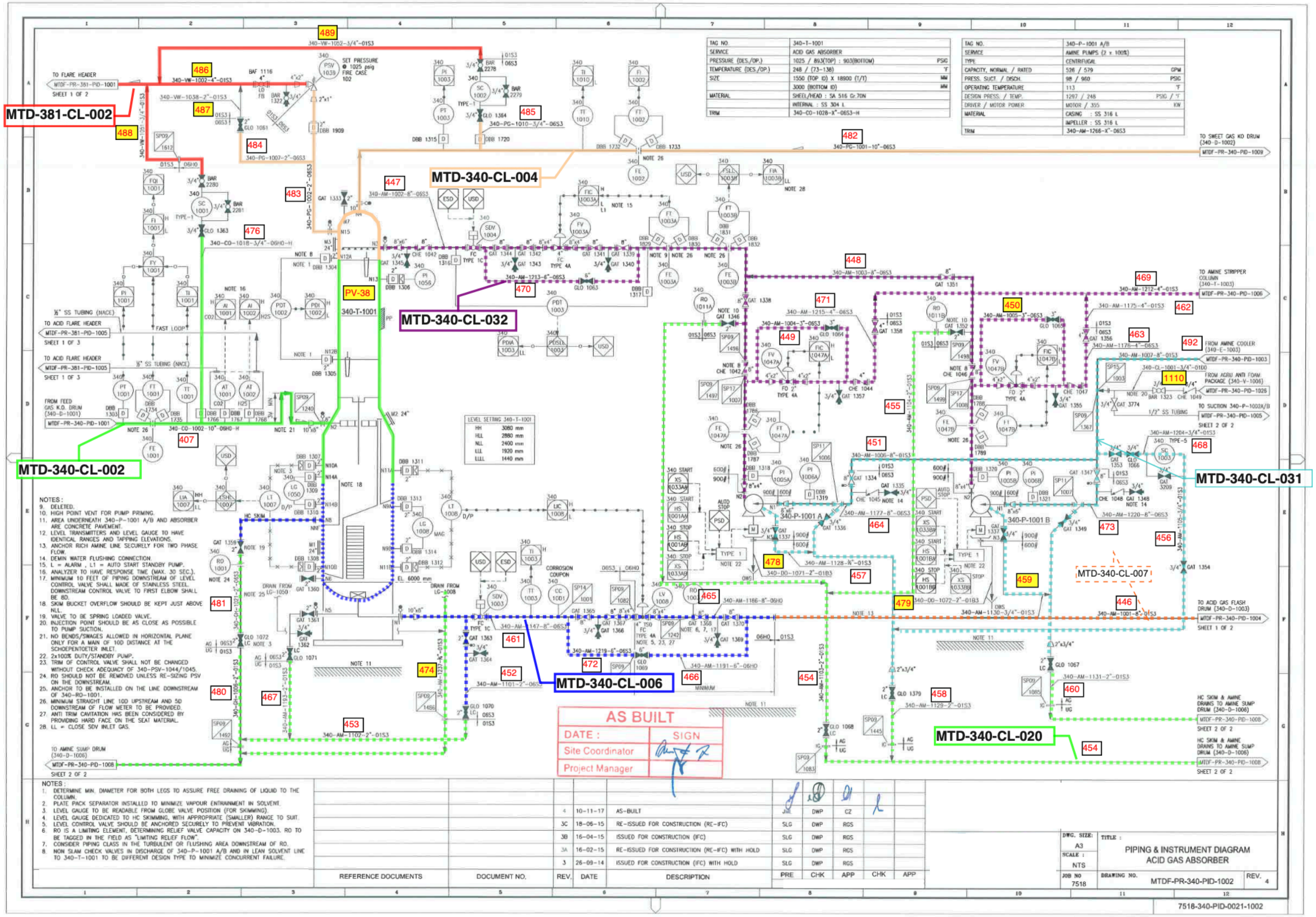
JOB NO 7518

TITLE : PIPING & INSTRUMENT DIAGRAM SWEET GAS K.O DRUM

DRAWING NO. MTDF-PR-340-PID-1009

REV. 4

7518-340-PID-0021-1009



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MTD-340-CL-032
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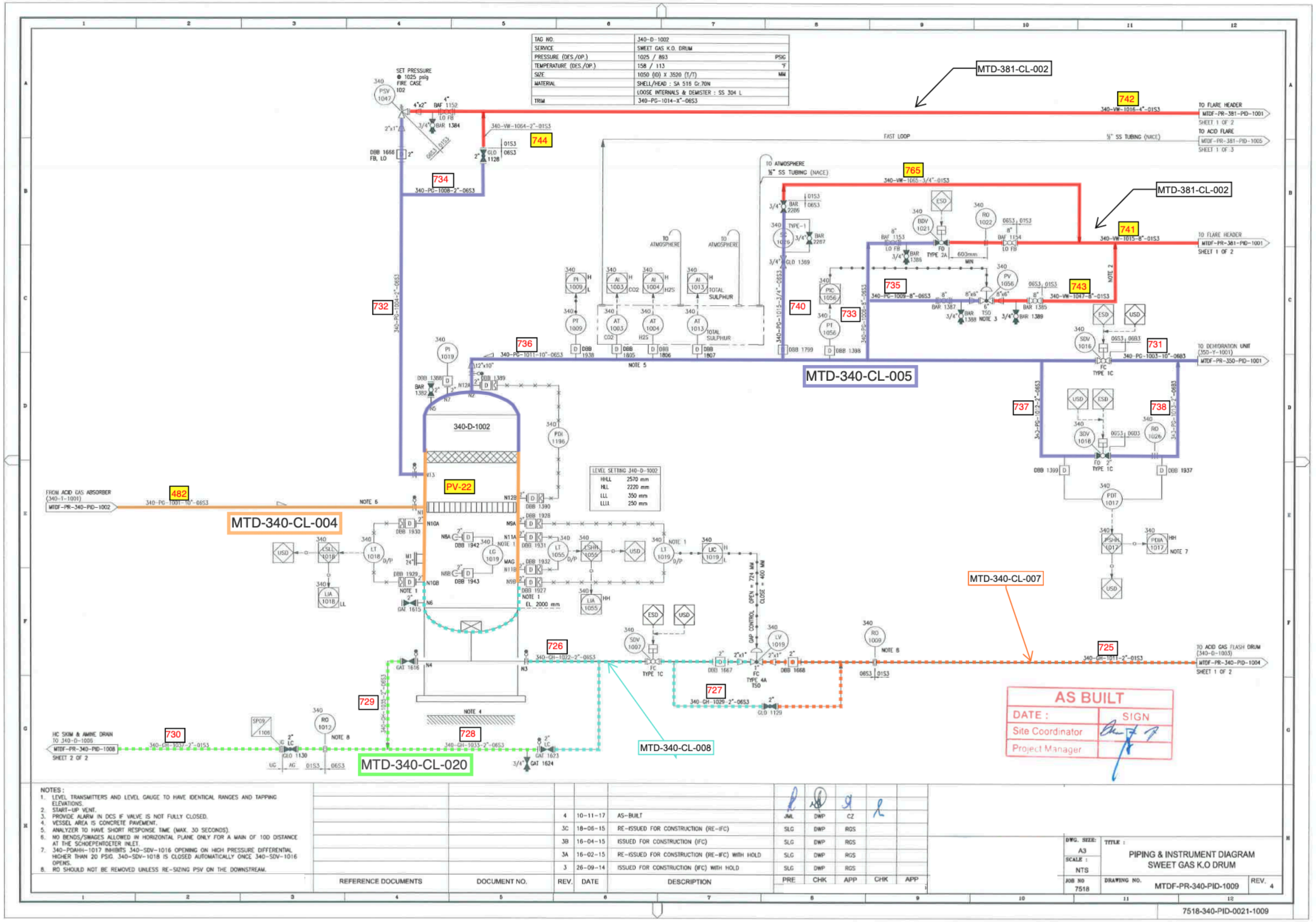
MTD-340-CL-006
MTD-340-CL-031
MTD-340-CL-007
MTD-340-CL-020
PV-38
340-T-1001
340-P-1001 A
340-P-1001 B
AS BUILT
DATE :
SIGN
Site Coordinator
Project Manager
PIPING & INSTRUMENT DIAGRAM
ACID GAS ABSORBER
MTDF-PR-340-PID-1002
7518-340-PID-0021-1002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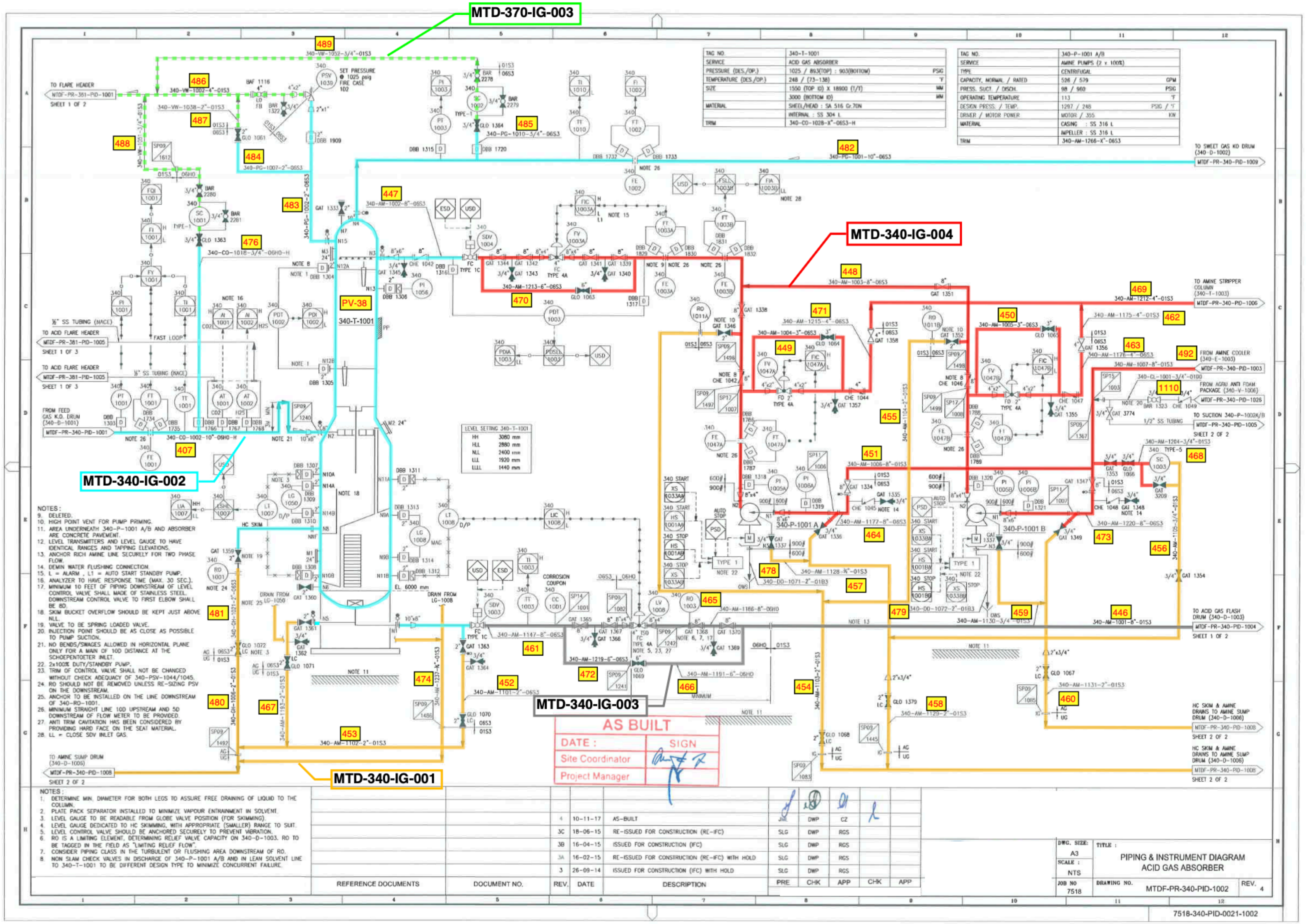
AS BUILT
DATE :
SIGN
Site Coordinator
Project Manager
REFERENCE DOCUMENTS
DOCUMENT NO.
REV.
DATE
DESCRIPTION
PIPING & INSTRUMENT DIAGRAM
SWEET GAS K.O DRUM
MTDF-PR-340-PID-1009
7518-340-PID-0021-1009



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MTD-340-IG-003
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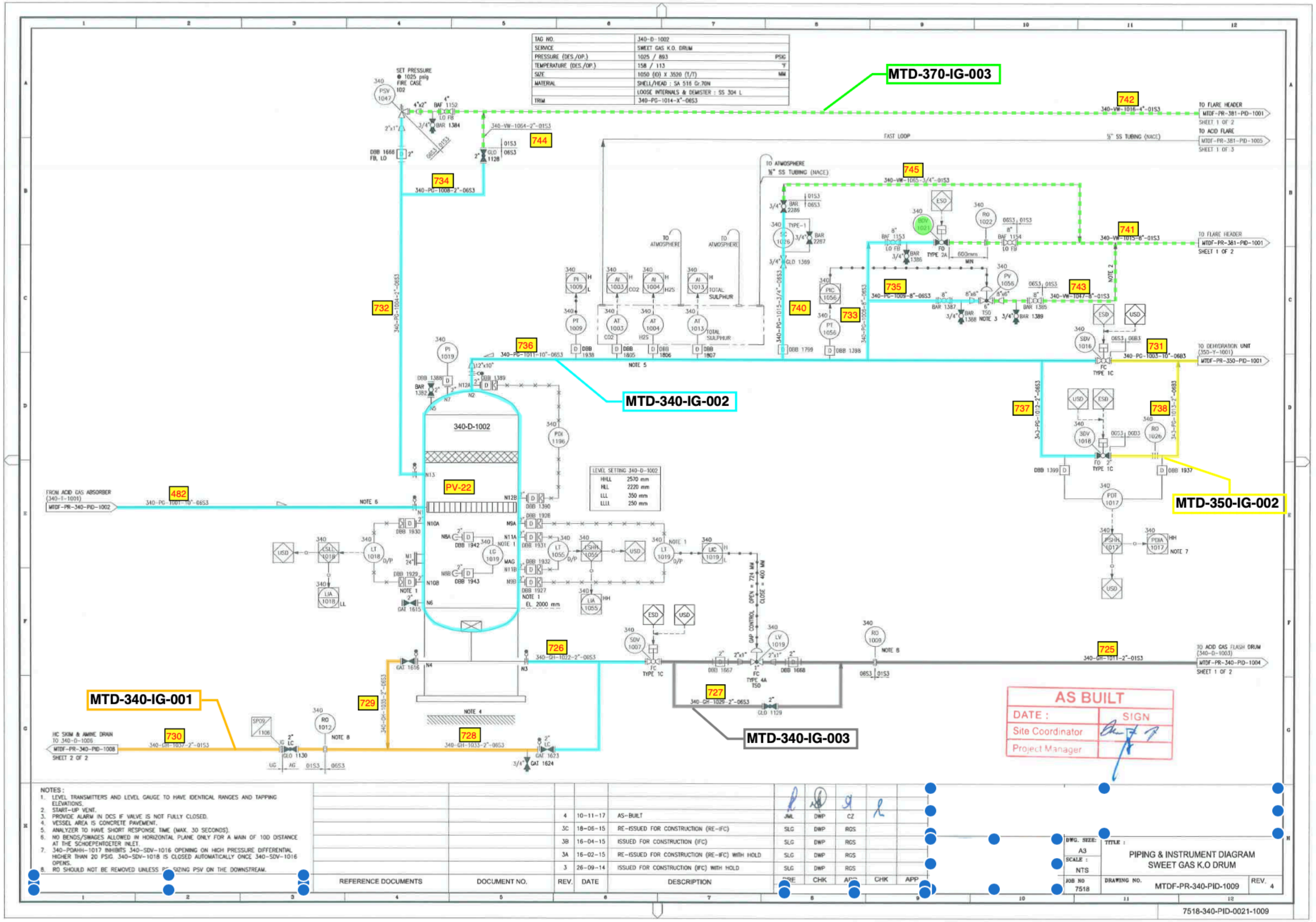
PV-38
340-P-1001 A
340-P-1001 B
AS BUILT
DATE :
SIGN
Site Coordinator
Project Manager
REFERENCE DOCUMENTS
DOCUMENT NO.
REV.
DATE
DESCRIPTION
PRE
CHK
APP
4 10-11-17 AS-BUILT
3C 18-06-15 RE-ISSUED FOR CONSTRUCTION (RE-IFC)
3B 16-04-15 ISSUED FOR CONSTRUCTION (IFC)
3A 16-02-15 RE-ISSUED FOR CONSTRUCTION (RE-IFC) WITH HOLD
3 26-09-14 ISSUED FOR CONSTRUCTION (IFC) WITH HOLD
TITLE : PIPING & INSTRUMENT DIAGRAM ACID GAS ABSORBER
DWG. SIZE: A3
SCALE : NTS
JOB NO 7518
DRAWING NO. MTDF-PR-340-PID-1002
REV. 4
7518-340-PID-0021-1002



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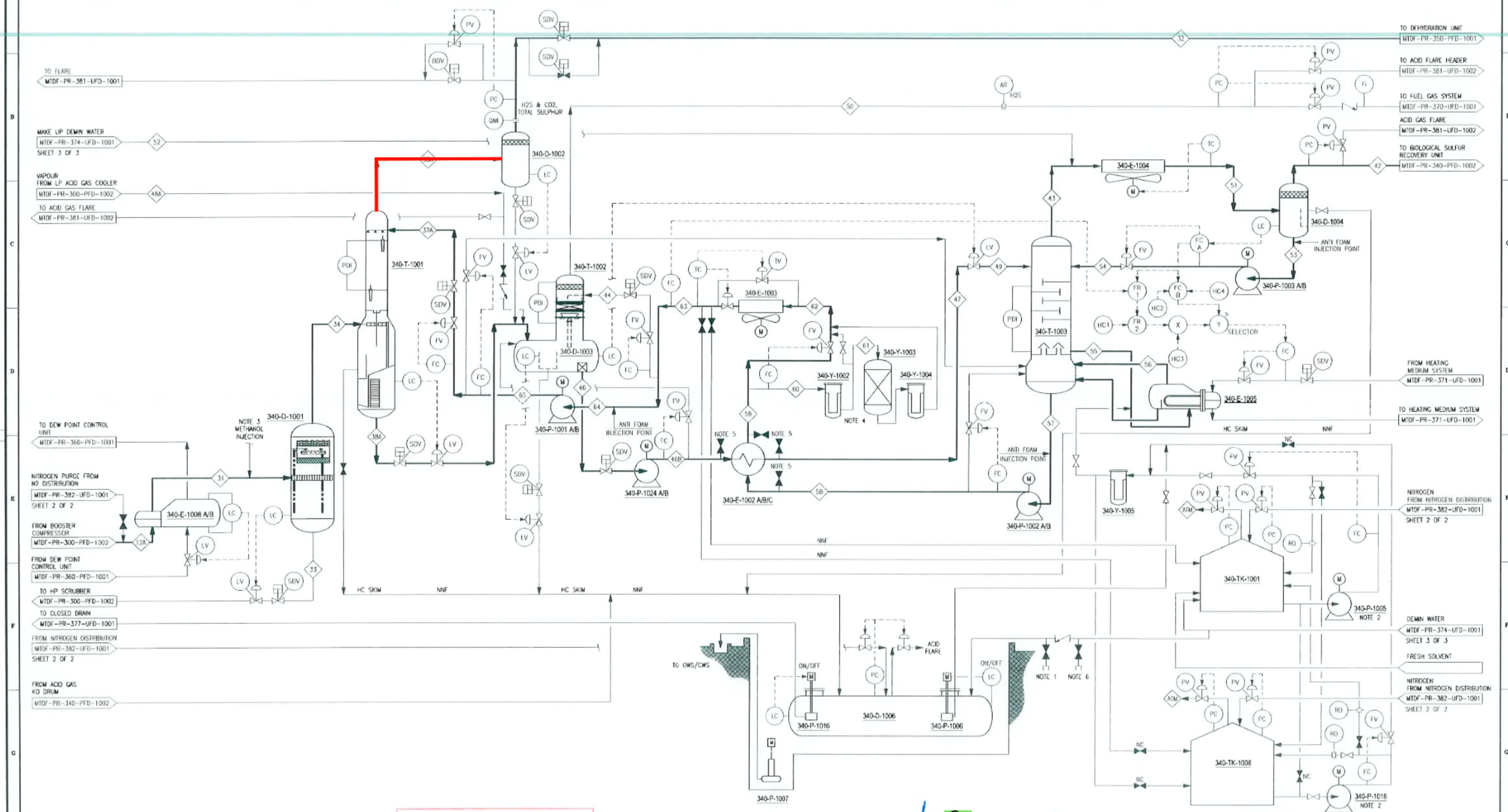
MTD-350-IG-002
MTD-340-IG-001
MTD-340-IG-003
340-D-1002
PV-22
AS BUILT
DATE :
SIGN
Site Coordinator
Project Manager
NOTES :
1. LEVEL TRANSMITTERS AND LEVEL GAUGE TO HAVE IDENTICAL RANGES AND TAPPING ELEVATIONS.
2. START-UP VENT.
3. PROVIDE ALARM IN DCS IF VALVE IS NOT FULLY CLOSED.
4. VESSEL AREA IS CONCRETE PAVEMENT.
5. ANALYZER TO HAVE SHORT RESPONSE TIME (MAX. 30 SECONDS).
6. NO BENDS/SWAGES ALLOWED IN HORIZONTAL PLANE ONLY FOR A MAIN OF 10D DISTANCE AT THE SCHOEPENTOETER INLET.
7. 340-PDAHH-1017 INHIBITS 340-SDV-1016 OPENING ON HIGH PRESSURE DIFFERENTIAL HIGHER THAN 20 PSIG. 340-SDV-1018 IS CLOSED AUTOMATICALLY ONCE 340-SDV-1016 OPENS.
8. RO SHOULD NOT BE REMOVED UNLESS RE-SIZING PSV ON THE DOWNSTREAM.
REFERENCE DOCUMENTS
DOCUMENT NO.
4 10-11-17 AS-BUILT JML DWP CZ
3C 18-06-15 RE-ISSUED FOR CONSTRUCTION (RE-IFC) SLG DWP RGS
3B 16-04-15 ISSUED FOR CONSTRUCTION (IFC) SLG DWP RGS
3A 16-02-15 RE-ISSUED FOR CONSTRUCTION (RE-IFC) WITH HOLD SLG DWP RGS
3 26-09-14 ISSUED FOR CONSTRUCTION (IFC) WITH HOLD SLG DWP RGS
REV. DATE DESCRIPTION PRE CHK APP CHK APP
DWG. SIZE: A3
SCALE : NTS
JOB NO 7518
TITLE : PIPING & INSTRUMENT DIAGRAM SWEET GAS K.O DRUM
DRAWING NO. MTDF-PR-340-PID-1009
REV. 4
7518-340-PID-0021-1009

APPENDIX D – PROCESS FLOW DIAGRAM

340-D-1001 FEED GAS KO DRUM	340-D-1003 ACID GAS FLASH DRUM	340-D-1006 AMINE SUMP DRUM	340-E-1003 AMINE COOLER	340-E-1005 STRIPPER REBOILER	340-P-1001-A/B AMINE PUMPS	340-P-1003 A/B STRIPPER REFLUX PUMPS	340-P-1006 AMINE SUMP PUMP	340-P-1016 DRAIN HYDROCARBON PUMP	340-P-1024 A/B RICH AMINE PUMPS	340-T-1002 FLASH GAS ABSORBER	340-TK-1001 AMINE TANK	340-Y-1002 AMINE MECHANICAL FILTER	340-Y-1004 AMINE CARBON AFTER FILTER
340-D-1002 SWEET GAS KO DRUM	340-D-1004 STRIPPER REFLUX DRUM	340-E-1002A/B/C AMINE / AMINE HEAT EXCHANGERS	340-E-1004 STRIPPER CONDENSER	340-E-1008A/B FEED GAS PROPANE CHILLERS	340-P-1002 A/B AMINE BOOSTER PUMPS	340-P-1005 AMINE TRANSFER PUMP	340-P-1007 SUMP PUMP	340-P-1018 WASH WATER PUMP	340-T-1001 ACID GAS ABSORBER	340-T-1003 AMINE STRIPPER COLUMN	340-TK-1006 WASH WATER TANK	340-Y-1003 AMINE ACTIVATED CARBON FILTER	340-Y-1005 AMINE DRAIN FILTER



NOTES :

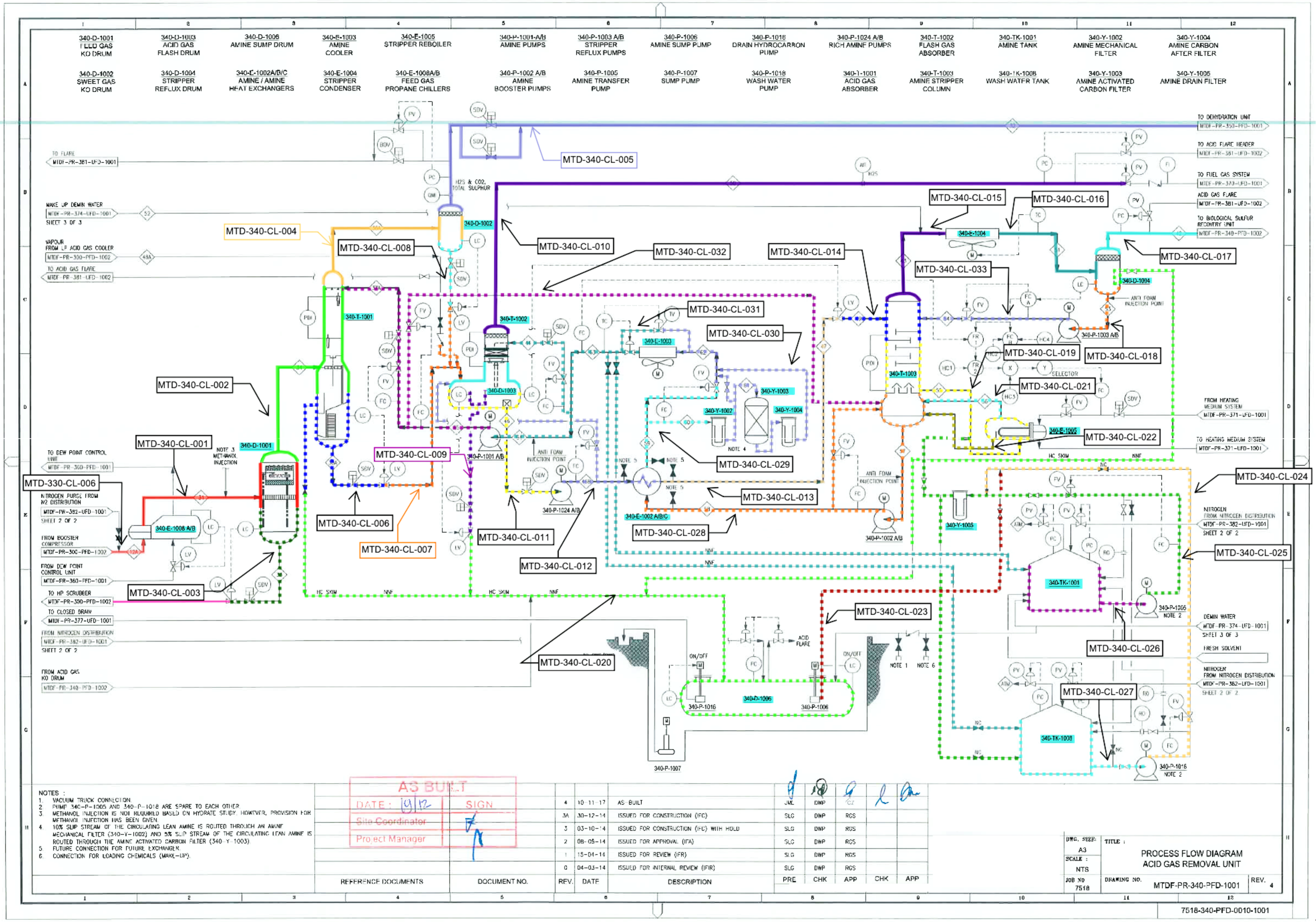
1. VACUUM TRUCK CONNECTION.
2. PUMP 340-P-1005 AND 340-P-1018 ARE SPARE TO EACH OTHER.
3. METHANOL INJECTION IS NOT REQUIRED BASED ON HYDRATE STUDY. HOWEVER, PROVISION FOR METHANOL INJECTION HAS BEEN GIVEN.
4. 10% SLIP STREAM OF THE CIRCULATING LEAN AMINE IS ROUTED THROUGH AN AMINE MECHANICAL FILTER (340-Y-1002) AND 5% SLIP STREAM OF THE CIRCULATING LEAN AMINE IS ROUTED THROUGH THE AMINE ACTIVATED CARBON FILTER (340-Y-1003).
5. FUTURE CONNECTION FOR FUTURE EXCHANGER.
6. CONNECTION FOR LOADING CHEMICALS (MAKE-UP).
7

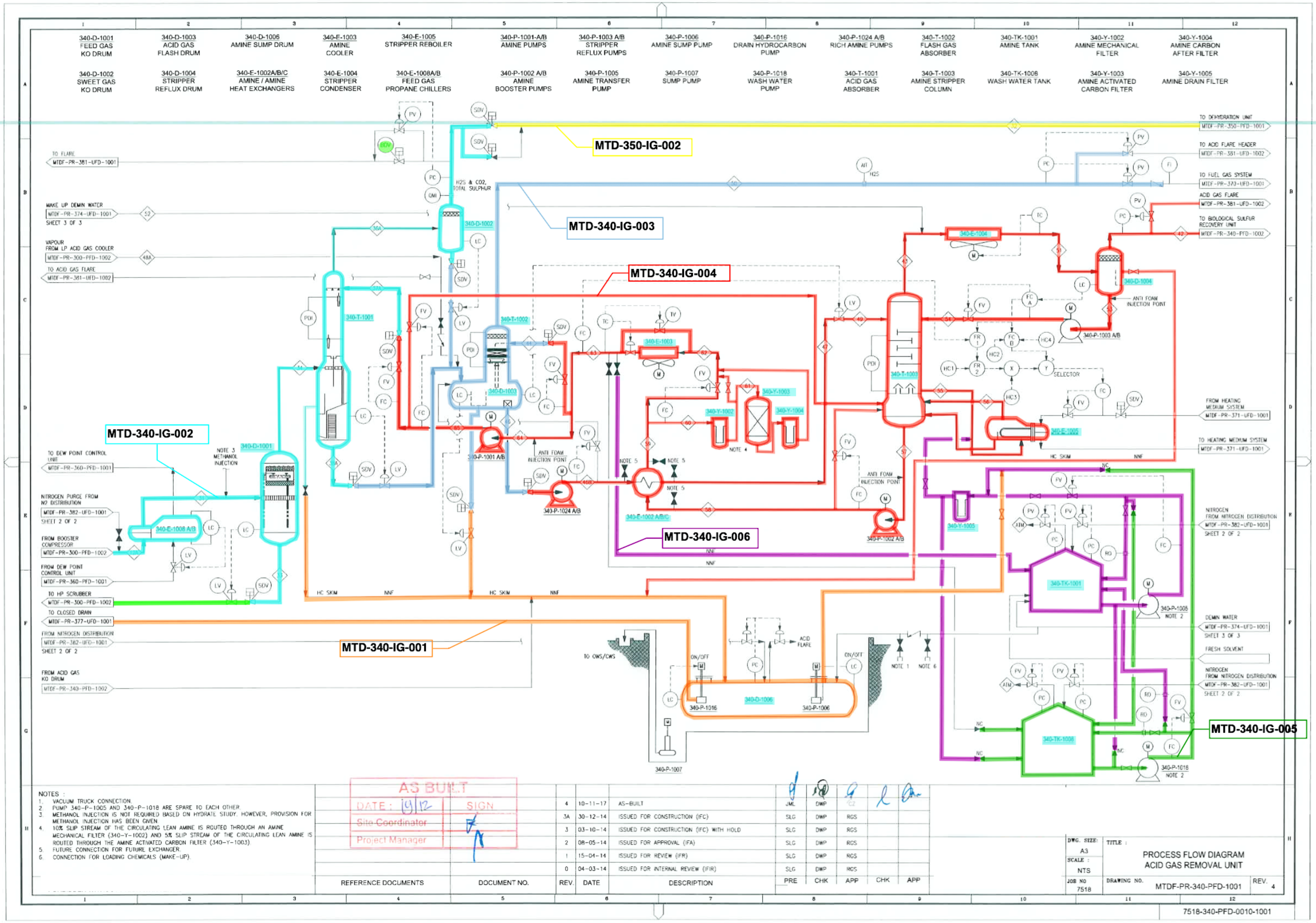
AS BUILT
DATE : 19/12 | SIGN
Site Coordinator
Project Manager

REFERENCE DOCUMENTS	DOCUMENT NO.	REV.	DATE	DESCRIPTION	PRE	CHK	APP	CHK	APP
		4	10-11-17	AS-BUILT	JML	DWP	CZ		
		3A	30-12-14	ISSUED FOR CONSTRUCTION (IFC)	SLG	DWP	RGS		
		3	03-10-14	ISSUED FOR CONSTRUCTION (IFC) WITH HOLD	SLG	DWP	RGS		
		2	08-05-14	ISSUED FOR APPROVAL (IFA)	SLG	DWP	RGS		
		1	15-04-14	ISSUED FOR REVIEW (IFR)	SLG	DWP	RGS		
		0	04-03-14	ISSUED FOR INTERNAL REVIEW (IFIR)	SLG	DWP	RGS		

DWG. SIZE: A3
SCALE : NTS
TITLE : PROCESS FLOW DIAGRAM ACID GAS REMOVAL UNIT
JOB NO 7518
DRAWING NO. MTDF-PR-340-PFD-1001
REV. 4

7518-340-PFD-0010-1001


340-D-1001 FEED GAS KO DRUM
340-D-1003 ACID GAS FLASH DRUM
340-D-1006 AMINE SUMP DRUM
340-E-1003 AMINE COOLER
340-E-1005 STRIPPER REBOILER
340-P-1001-A/B AMINE PUMPS
340-P-1003 A/B STRIPPER REFLUX PUMPS
340-P-1006 AMINE SUMP PUMP
340-P-1016 DRAIN HYDROCARBON PUMP
340-P-1024 A/B RICH AMINE PUMPS
340-T-1002 FLASH GAS ABSORBER
340-TK-1001 AMINE TANK
340-Y-1002 AMINE MECHANICAL FILTER
340-Y-1004 AMINE CARBON AFTER FILTER
340-D-1002 SWEET GAS KO DRUM
340-D-1004 STRIPPER REFLUX DRUM
340-E-1002A/B/C AMINE / AMINE HEAT EXCHANGERS
340-E-1004 STRIPPER CONDENSER
340-E-1008A/B FEED GAS PROPANE CHILLERS
340-P-1002 A/B AMINE BOOSTER PUMPS
340-P-1005 AMINE TRANSFER PUMP
340-P-1007 SUMP PUMP
340-P-1018 WASH WATER PUMP
340-T-1001 ACID GAS ABSORBER
340-T-1003 AMINE STRIPPER COLUMN
340-TK-1008 WASH WATER TANK
340-Y-1003 AMINE ACTIVATED CARBON FILTER
340-Y-1005 AMINE DRAIN FILTER
TO DEHYDRATION UNIT MTDF-PR-350-PFD-1001
TO ACID FLARE HEADER MTDF-PR-381-UFD-1002
TO FUEL GAS SYSTEM
ACID GAS FLARE
TO BIOLOGICAL SULFUR RECOVERY UNIT
TO FLARE MTDF-PR-381-UFD-1001
MAKE UP DEMIN WATER MTDF-PR-374-UFD-1001 SHEET 3 OF 3
VAPOUR FROM LP ACID GAS COOLER MTDF-PR-300-PFD-1002
TO ACID GAS FLARE MTDF-PR-381-UFD-1002
TO DEW POINT CONTROL UNIT MTDF-PR-360-PFD-1001
NITROGEN PURGE FROM N2 DISTRIBUTION
FROM BOOSTER COMPRESSOR MTDF-PR-300-PFD-1002
FROM DEW POINT CONTROL UNIT MTDF-PR-360-PFD-1001
TO HP SCRUBBER MTDF-PR-330-PFD-1002
TO CLOSED DRAIN MTDF-PR-377-UFD-1001
FROM NITROGEN DISTRIBUTION
FROM ACID GAS KO DRUM
FROM HEATING MEDIUM SYSTEM MTDF-PR-371-UFD-1001
TO HEATING MEDIUM SYSTEM MTDF-PR-371-UFD-1001
NITROGEN FROM NITROGEN DISTRIBUTION MTDF-PR-382-UFD-1001 SHEET 2 OF 2
DEMIN WATER MTDF-PR-374-UFD-1001 SHEET 3 OF 3
FRESH SOLVENT
H2S & CO2, TOTAL SULPHUR
ANTI FOAM INJECTION POINT
SELECTOR
ON/OFF
MTD-340-CL-001
MTD-340-CL-002
MTD-340-CL-003
MTD-340-CL-004
MTD-340-CL-005
MTD-340-CL-006
MTD-340-CL-007
MTD-340-CL-008
MTD-340-CL-009
MTD-340-CL-010
MTD-340-CL-011
MTD-340-CL-012
MTD-340-CL-013
MTD-340-CL-014
MTD-340-CL-015
MTD-340-CL-016
MTD-340-CL-017
MTD-340-CL-018
MTD-340-CL-019
MTD-340-CL-020
MTD-340-CL-021
MTD-340-CL-022
MTD-340-CL-023
MTD-340-CL-024
MTD-340-CL-025
MTD-340-CL-026
MTD-340-CL-027
MTD-340-CL-028
MTD-340-CL-029
MTD-340-CL-030
MTD-340-CL-031
MTD-340-CL-032
MTD-340-CL-033
MTD-330-CL-006
NOTES :
1. VACUUM TRUCK CONNECTION.
2. PUMP 340-P-1005 AND 340-P-1018 ARE SPARE TO EACH OTHER.
3. METHANOL INJECTION IS NOT REQUIRED BASED ON HYDRATE STUDY. HOWEVER, PROVISION FOR METHANOL INJECTION HAS BEEN GIVEN.
4. 10% SLIP STREAM OF THE CIRCULATING LEAN AMINE IS ROUTED THROUGH AN AMINE MECHANICAL FILTER (340-Y-1002) AND 5% SLIP STREAM OF THE CIRCULATING LEAN AMINE IS ROUTED THROUGH THE AMINE ACTIVATED CARBON FILTER (340-Y-1003).
5. FUTURE CONNECTION FOR FUTURE EXCHANGER.
6. CONNECTION FOR LOADING CHEMICALS (MAKE-UP).
AS BUILT
DATE :
SIGN
Site Coordinator
Project Manager
REFERENCE DOCUMENTS
DOCUMENT NO.
4 10-11-17 AS-BUILT
3A 30-12-14 ISSUED FOR CONSTRUCTION (IFC) SLG DWP RGS
3 03-10-14 ISSUED FOR CONSTRUCTION (IFC) WITH HOLD SLG DWP RGS
2 08-05-14 ISSUED FOR APPROVAL (IFA) SLG DWP RGS
1 15-04-14 ISSUED FOR REVIEW (IFR) SLG DWP RGS
0 04-03-14 ISSUED FOR INTERNAL REVIEW (IFIR) SLG DWP RGS
REV. DATE DESCRIPTION PRE CHK APP CHK APP
DWG. SIZE: A3
SCALE : NTS
JOB NO 7518
TITLE : PROCESS FLOW DIAGRAM ACID GAS REMOVAL UNIT
DRAWING NO. MTDF-PR-340-PFD-1001
REV. 4
7518-340-PFD-0010-1001


340-D-1001 FEED GAS KO DRUM
340-D-1002 SWEET GAS KO DRUM
340-D-1003 ACID GAS FLASH DRUM
340-D-1004 STRIPPER REFLUX DRUM
340-D-1006 AMINE SUMP DRUM
340-E-1002A/B/C AMINE / AMINE HEAT EXCHANGERS
340-E-1003 AMINE COOLER
340-E-1004 STRIPPER CONDENSER
340-E-1005 STRIPPER REBOILER
340-E-1008A/B FEED GAS PROPANE CHILLERS
340-P-1001-A/B AMINE PUMPS
340-P-1002 A/B AMINE BOOSTER PUMPS
340-P-1003 A/B STRIPPER REFLUX PUMPS
340-P-1005 AMINE TRANSFER PUMP
340-P-1006 AMINE SUMP PUMP
340-P-1007 SUMP PUMP
340-P-1016 DRAIN HYDROCARBON PUMP
340-P-1018 WASH WATER PUMP
340-P-1024 A/B RICH AMINE PUMPS
340-T-1001 ACID GAS ABSORBER
340-T-1002 FLASH GAS ABSORBER
340-T-1003 AMINE STRIPPER COLUMN
340-TK-1001 AMINE TANK
340-TK-1006 WASH WATER TANK
340-Y-1002 AMINE MECHANICAL FILTER
340-Y-1003 AMINE ACTIVATED CARBON FILTER
340-Y-1004 AMINE CARBON AFTER FILTER
340-Y-1005 AMINE DRAIN FILTER
MTD-350-IG-002
MTD-340-IG-003
MTD-340-IG-004
MTD-340-IG-002
MTD-340-IG-006
MTD-340-IG-001
MTD-340-IG-005
TO DEHYDRATION UNIT MTDF-PR-350-PFD-1001
TO ACID FLARE HEADER MTDF-PR-381-UFD-1002
TO FUEL GAS SYSTEM MTDF-PR-373-UFD-1001
ACID GAS FLARE MTDF-PR-381-UFD-1002
TO BIOLOGICAL SULFUR RECOVERY UNIT MTDF-PR-340-PFD-1002
TO FLARE MTDF-PR-381-UFD-1001
MAKE UP DEMIN WATER MTDF-PR-374-UFD-1001 SHEET 3 OF 3
VAPOUR FROM LP ACID GAS COOLER MTDF-PR-300-PFD-1002
TO ACID GAS FLARE MTDF-PR-381-UFD-1002
TO DEW POINT CONTROL UNIT MTDF-PR-360-PFD-1001
NITROGEN PURGE FROM N2 DISTRIBUTION MTDF-PR-382-UFD-1001 SHEET 2 OF 2
FROM BOOSTER COMPRESSOR MTDF-PR-300-PFD-1002
FROM DEW POINT CONTROL UNIT MTDF-PR-360-PFD-1001
TO HP SCRUBBER MTDF-PR-300-PFD-1002
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FROM NITROGEN DISTRIBUTION MTDF-PR-382-UFD-1001 SHEET 2 OF 2
FROM ACID GAS KO DRUM MTDF-PR-340-PFD-1002
FROM HEATING MEDIUM SYSTEM MTDF-PR-371-UFD-1001
TO HEATING MEDIUM SYSTEM MTDF-PR-371-UFD-1001
NITROGEN FROM NITROGEN DISTRIBUTION MTDF-PR-382-UFD-1001 SHEET 2 OF 2
DEMIN WATER MTDF-PR-374-UFD-1001 SHEET 3 OF 3
FRESH SOLVENT
H2S & CO2, TOTAL SULPHUR
ANTI FOAM INJECTION POINT
NOTE 3 METHANOL INJECTION
SELECTOR
HC SKIM
NNF
TO OWS/CWS
ACID FLARE
ON/OFF
NOTES :
1. VACUUM TRUCK CONNECTION.
2. PUMP 340-P-1005 AND 340-P-1018 ARE SPARE TO EACH OTHER.
3. METHANOL INJECTION IS NOT REQUIRED BASED ON HYDRATE STUDY. HOWEVER, PROVISION FOR METHANOL INJECTION HAS BEEN GIVEN.
4. 10% SLIP STREAM OF THE CIRCULATING LEAN AMINE IS ROUTED THROUGH AN AMINE MECHANICAL FILTER (340-Y-1002) AND 5% SLIP STREAM OF THE CIRCULATING LEAN AMINE IS ROUTED THROUGH THE AMINE ACTIVATED CARBON FILTER (340-Y-1003).
5. FUTURE CONNECTION FOR FUTURE EXCHANGER.
6. CONNECTION FOR LOADING CHEMICALS (MAKE-UP).
AS BUILT
DATE :
SIGN
Site Coordinator
Project Manager
4 10-11-17 AS-BUILT
3A 30-12-14 ISSUED FOR CONSTRUCTION (IFC) SLG DWP RGS
3 03-10-14 ISSUED FOR CONSTRUCTION (IFC) WITH HOLD SLG DWP RGS
2 08-05-14 ISSUED FOR APPROVAL (IFA) SLG DWP RGS
1 15-04-14 ISSUED FOR REVIEW (IFR) SLG DWP RGS
0 04-03-14 ISSUED FOR INTERNAL REVIEW (IFIR) SLG DWP RGS
REFERENCE DOCUMENTS
DOCUMENT NO.
REV. DATE DESCRIPTION PRE CHK APP CHK APP
DWG. SIZE: A3
SCALE : NTS
JOB NO 7518
TITLE : PROCESS FLOW DIAGRAM ACID GAS REMOVAL UNIT
DRAWING NO. MTDF-PR-340-PFD-1001
REV. 4
7518-340-PFD-0010-1001

APPENDIX E – RISK BASED INSPECTION CALCULATION

1. **Probability of Failure**

1. **Asset**

Line/Tag Number	340-PG-1001-10-06S3
Type	Pipe 10"
Material	Carbon Steel ASTM A106 Gr B
Fluid Handle	C1-C2
From	Acid Gas Absorber (340-T-1001)
To	Sweet Gas KO Drum (340-D-1002)
Unit	AGRU - SRU
P&ID No.	MTDF-PR-340-PID-1002 MTDF-PR-340-PID-1009

2. **General Properties**

Material of Construction	Carbon or Low Alloy
Lining Present	Yes
Insulation Present	No
Exposed to Chloride and Water	Yes
Operating Temperature (°C)	30
Operating Pressure (MPa)	6,16
Date of Installation	09/03/17

3. **Damage Factors Selection**

Table E. 1 21 Types of Damage Factor and Its Description

No	Damage Factor	Symbol	Description	Applied?
1	Thinning	D_f^{thin}	This is a required factor that applies to all components.	Yes
2	Component Lining	D_f^{elin}	The component includes a lining (either inorganic or organic).	No
3	SCC - Caustic Cracking	D_f^{caustic}	The Component is composed of a carbon or low alloy steel and there are any concentrations of caustic elements in the process environment.	No
4	SCC - Amine Cracking	D_f^{amine}	The component is composed of a carbon or low alloy steel and the process environment has any concentration present of acid gas treating amines (e.g., DIPA, MEA, etc.).	No
5	SCC - Sulfide Stress Cracking	D_f^{SSC}	The component is composed of carbon or low alloy steel and it operates in an environment that contains any concentration of H2S and water.	No

6	SCC - HIC/SOHIC-H2S	$D_f^{HIC/SOHIC-H2S}$	The component is composed of a carbon or low alloy steel and there is H2S and water in any concentration in the process environment.	No
7	SCC - Alkaline Carbonate Stress Corrosion Cracking	D_f^{ACSCC}	The component is composed of a carbon or low alloy steel and there is sour water with pH > 7.5 in the process environment in any concentration.	No
8	SCC - Polythionic Acid Stress Corrosion Cracking	D_f^{PTA}	The component is composed of a nickel-based alloy or an austenitic stainless steel and it is exposed to sulfur bearing compounds.	No
9	SCC - Chloride Stress Corrosion Cracking	D_f^{ClSCC}	The component is composed of a austenitic stainless steel and it is exposed to water and chlorides with the operating temperature being above 38 oC.	No
10	SCC - Hydrogen Stress Cracking in Hydrofluoric Acid	D_f^{HSC-HF}	The component is composed of a carbon or low alloy steel and it is exposed to any concentration of hydrofluoric acid.	No
11	SCC - HIC/SOHIC-HF	$D_f^{HIC/SOHIC-HF}$	The component is composed of a carbon or low alloy steel and it is exposed to any concentration of hydrofluoric acid.	No
12	External Corrosion - Ferritic Component	D_f^{extcor}	Select this factor if the component is un-insulated and subject to any of the following conditions: • Some areas are exposed to steam vents, deluge systems or cooling tower mist overlays. • Some areas are subject to acid vapors, process spills or the ingress of moisture. • The component is composed of carbon steel and the operating temperature is 23°C - 121°C. • The component has deteriorated wrapping or coatings. • The component is subject to frequent outages. • The component does not normally operate 12°C - 177°C, but does periodically heat or cool in this range. • The component consistently operates below the atmospheric dew point.	Yes

			• The component has un-insulated protrusions or nozzles in cold conditions.	
13	Corrosion Under Insulation (CUI) - Ferritic Component	D_f^{CUIF}	Component and/or locations are suspect. i.e., visually damaged insulation areas or penetrations.	No
14	ExtClSCC - Austenitic Component	$D_f^{ext-ClSCC}$	The component is composed of austenitic stainless steel and its external surface is exposed to fluids, mists or solids containing chloride and either the operating temperature is 50°C - 150°C or the component is intermittently in this range due to heating or cooling.	No
15	External CUI ClSCC-Austenitic Component	$D_f^{CUI-ClSCC}$	The component is composed of austenitic stainless steel and its external surface is exposed to fluids, mists or solids containing chloride and either the operating temperature is 50°C - 150°C or the component is intermittently in this range due to heating or cooling.	No
16	Brittle Fracture	D_f^{brit}	The material is composed of carbon steel or low-alloy steel (see the table in the help file for the available steel types) and the Minimum Design Metal Temperature is either unknown or known but the component may operate below it under normal conditions.	No
17	Low Alloy Steel Embrittlement	D_f^{tempe}	The material is composed of 1Cr-0.5Mo, 1.25Cr-0.5Mo, 2.25Cr-1Mo, or 3Cr-1 Mo low alloy steel. The operating temperature is 343 °C - 577 °C (650 °F - 1070 °F).	No
18	High Temperature Hydrogen Attack (HTHA)	D_f^{htha}	The component is composed of carbon steel, C-1⁄2 Mo, or a Cr-Mo low alloy steel (such as 1⁄2 Cr-1⁄2 Mo, 1 Cr-1⁄2 Mo, 11⁄4 Cr-1⁄2 Mo, 21⁄4 Cr-1 Mo, 3 Cr-1 Mo, 5 Cr-1⁄2 Mo, 7 Cr-1 Mo, and 9 Cr-1 Mo). The operating temperature is greater than 177 °C (350 °F). The operating hydrogen partial pressure is greater than 0.345 MPa (50 psia).	No
19	885 °F Embrittlement	D_f^{885F}	The material is composed of high chromium (>12 % Cr) ferritic steel. The operating temperature is 371 °C - 566 °C (700 °F - 1050 °F).	No

20	Sigma Phase Embrittlement	D_f^{sigma}	The material is composed of austenitic stainless steel. The operating temperature is 593 °C - 927 °C (1100 °F - 1700 °F).	No
21	Piping Mechanical Fatigue	D_f^{mfat}	Select this factor if the component is a pipe and any of the following conditions are true: • The pipe system has had previous fatigue failures. • There is audible and/or visible shaking (continuous or intermittent) in the pipe system. • The pipe system is connected (directly or indirectly) to a cyclic vibration source within 15.24 meters.	No

4. Calculation

A. Generic Failure Frequency

Equipment Type : Pipe
Diameter : 10 inches
Component Type : PIPE-10

Table E. 2 Generic Failure Frequency Score

Tag Number	Type	As a Function of Hole Size (failures/yr)				gfftotal (falilures/yr)
		Small	Medium	Large	Rupture	
340-PG-1001-10-06S3	PIPE-10	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05

B. Damage Factor

Thinning Damage Factor

$\mathbf{D}_{f-gov}^{\text{thin}}$: Thinning

$D_{f-gov}^{\text{thin}} = min\left|D_f^{\text{thin}}, D_f^{\text{elin}}\right|$

$D_{f-gov}^{\text{thin}} = D_f^{\text{thin}}$

$D_{f-gov}^{\text{thin}} = 1.059\text{E} + 00$

External Damage Factor

D_{f-gov}^{extd} : External

$D_{f-gov}^{\text{extd}} = max \mid D_f^{\text{extcor}}, D_f^{\text{CUIF}}, D_f^{\text{ext}-ClSCC}, D_f^{\text{cUI-ClSCC}} \mid$

$D_{f-gov}^{\text{extd}} = 0.092\text{E} + 00$

Total Damage Factor

$D_{f-\text{total}} = D_{f-gov}^{\text{thin}} + D_{f-gov}^{\text{extd}}$

$D_{f-\text{total}} = (1.059\text{E}+00) + (0.092\text{E}+00)$
$D_{f-\text{total}} = 1.150$

C. Management System Factor

To determine the value of management system factor, we can do an assessment by following management systems work book in part 2 - Annex 2.A API RP 581. For this calculation, we assume the actual score of assessment is between 500 and 1000.

$$\text{pscore} = \frac{\text{score}}{1000} x\ 100\% = \frac{500}{1000} x\ 100 = 50\%$$

The scale recommended for converting a management systems evaluation score to a management systems factor is based on the assumption that the "average" plant would score 50% (500 out of a possible score of 1,000) on the management systems evaluation. The assumptions can be modified and improved over time as more data become available on management systems evaluation results.

$$F_{MS} = 10^{(-0.02\times \text{pscore} + 1)} = 1$$

D. The Probability of Failure (POF)

$P_f(\text{t}) = gff_{\text{total}} \cdot D_f(\text{t}) \cdot F_{MS}$
$P_f(\text{t}) = (3.06\text{E}-05) \cdot 1.150 \cdot 1$
$P_f(\text{t}) = 3.52\text{E}-05$

POF Category : 2 - Unlikely

2. Thinning Damage Factor

1. Asset

Line/Tag Number	340-PG-1001-10-06S3
Type	Pipe 10"
Material	Carbon Steel ASTM A106 Gr B
Fluid Handle	C1-C2
From	Acid Gas Absorber (340-T-1001)
To	Sweet Gas KO Drum (340-D-1002)
Unit	AGRU - SRU
P&ID No.	MTDF-PR-340-PID-1002 MTDF-PR-340-PID-1009

2. Component Data

Starting Date	09/03/17
Last Inspection	24/09/22
Thickness (mm)	14,15
Corrosion Allowance (in)	0,118
Max. Design Temperature (°C)	204,4
Min. Design Temperature (°C)	-28,9
Max. Design Pressure (MPa)	10,2
Operating Temperature (°C)	30
Operating Pressure (MPa)	6,16
Design Code	ASME B31.3
Equipment Type	Pipe
Component Type	PIPE - 10
Diameter (in)	10
Component Geometry Data	CYL, ELB
Material Specification	ASTM A106 Gr B
Yield Strength (MPa)	240
Tensile Strength (MPa)	415
Allowable Stress (MPa)	138
Weld Joint Efficiency	1
Heat Tracing	No

3. Calculation

a. Step 1. Determine the furnished thickness

t = 15.09 mm
age = 6 years

b. Step 2. Determine the corrosion rate for the base material

$C_{r,bm} = (t - t_{rdi})\text{age}$ mm/ year
$C_{r,bm} = 0.1567$ mm/ year

c. Step 3. Determine the time in-service

t_{rdi} = 14.15 mm
age_{tk} = 1 years
(Inspected on 24-09-2022)

d. Step 4. Determine the age of cladding

age_{rc} = − years (Cladding not applicable)

e. Step 5. Determine t_{min}

t_{min} = 12.98 mm

f. Step 6. Determine A_{rt} parameter

$$A_{rt} = \frac{C_{r,bm} \cdot age_{tk}}{t_{rdi}}$$

$$A_{rt} = \frac{0.1567 \cdot 1}{14.15}$$

$$A_{rt} = 0.011$$

g. Step 7. Calculate the flow stress

$$FS^{\text{Thin}} = \frac{(YS + TS)}{2} \cdot E \cdot 1.1$$

$$FS^{\text{Thin}} = \frac{(415 + 240)}{2} \cdot 1 \cdot 1.1$$

$$FS^{\text{Thin}} = 360.25$$

h. Step 8. Calculate the strength ratio parameter

$$SR_P^{\text{Thin}} = \frac{S \cdot E}{FS^{\text{Thin}}} \cdot \frac{\text{Max}(t_{min}, t_c)}{t_{rdi}}$$

$$SR_P^{\text{Thin}} = \frac{138 \cdot E}{360.25} \cdot \frac{12.98}{14.15}$$

$$SR_P^{\text{Thin}} = 0.351$$

i. Step 9. Determine the number of inspections N_A^{extcorr}, N_B^{extcorr}, N_C^{extcorr}, N_D^{extcorr}

$N_A^{\text{Thin}} = 0$
$N_B^{\text{Thin}} = 0$
$N_C^{\text{Thin}} = 1$
$N_D^{\text{Thin}} = 0$

Inspection Category : C – Fairly Effective

j. Step 10. Calculate the inspection effectiveness factors
Prior Probability : High Confidence Data
Conditional Probability : C – Fairly Effective

$$I_1^{\mathrm{Thin}} = \mathrm{Pr}_{p1}^{\mathrm{Thin}} \,.\, \left(\mathrm{Co}_{p1}^{\mathrm{ThinC}\ C}\right)^{N_C^{\mathrm{Thin}}}$$
$$I_1^{\mathrm{Thin}} = 0.8 \,.\, 0.5$$
$$I_1^{\mathrm{Thin}} = 0.4$$

$$I_2^{\mathrm{Thin}} = \mathrm{Pr}_{p2}^{\mathrm{Thin}} \,.\, \left(\mathrm{Co}_{p2}^{\mathrm{ThinC}\ C}\right)^{N_C^{\mathrm{Thin}}}$$
$$I_2^{\mathrm{Thin}} = 0.15 \,.\, 0.3$$
$$I_2^{\mathrm{Thin}} = 0.045$$

$$I_3^{\mathrm{Thin}} = \mathrm{Pr}_{p3}^{\mathrm{Thin}} \,.\, \left(\mathrm{Co}_{p3}^{\mathrm{ThinC}\ C}\right)^{N_C^{\mathrm{Thin}}}$$
$$I_3^{\mathrm{Thin}} = 0.05 \,.\, 0.2$$
$$I_3^{\mathrm{Thin}} = 0.01$$

k. Step 11. Calculate the posterior probabilities

$$Po_{p1}^{\mathrm{Thin}} = \frac{I_1^{\mathrm{Thin}}}{I_1^{\mathrm{Thin}} + I_2^{\mathrm{Thin}} + I_3^{\mathrm{Thin}}}$$
$$Po_{p1}^{\mathrm{Thin}} = \frac{0.4}{0.4 + 0.045 + 0.01}$$
$$Po_{p1}^{\mathrm{Thin}} = 0.879$$

$$Po_{p2}^{\mathrm{Thin}} = \frac{I_2^{\mathrm{Thin}}}{I_1^{\mathrm{Thin}} + I_2^{\mathrm{Thin}} + I_3^{\mathrm{Thin}}}$$
$$Po_{p2}^{\mathrm{Thin}} = \frac{0.045}{0.4 + 0.045 + 0.01}$$
$$Po_{p2}^{\mathrm{Thin}} = 0.099$$

$$Po_{p3}^{\mathrm{Thin}} = \frac{I_3^{\mathrm{Thin}}}{I_1^{\mathrm{Thin}} + I_2^{\mathrm{Thin}} + I_3^{\mathrm{Thin}}}$$
$$Po_{p3}^{\mathrm{Thin}} = \frac{0.01}{0.4 + 0.045 + 0.01}$$
$$Po_{p3}^{\mathrm{Thin}} = 0.022$$

l. Step 12. Calculate the parameters $\beta_1^{\text{Thin}}, \beta_2^{\text{Thin}}, \beta_3^{\text{Thin}}$ assigning $COV_{\Delta t} = 0.20,\ COV_{S_f} = 0.20$, and $COV_P = 0.05$ where $D_{S_1} = 1,\ D_{S_2} = 2$ and $D_{S_3} = 4$.

The parameters $\beta_1^{\text{Thin}}, \beta_2^{\text{Thin}}, \beta_3^{\text{Thin}}$ are the reliability indices for each damage states 1, 2 and 3. The D_{S_1}, D_{S_2} and D_{S_3} are the corrosion rate factors for damage states 1, 2 and 3.

$$\beta_1^{\text{Thin}} = \frac{1 - D_{S_1} \cdot A_{rt} - SR_p^{\text{Thin}}}{\sqrt{D_{S_1}^2 \cdot A_{rt}^2 \cdot COV_{\Delta t}^2 + \left(1 - D_{S_1} \cdot A_{rt}\right)^2 \cdot COV_{S_f}^2 + \left(SR_p^{\text{Thin}}\right)^2 \cdot COV_{\text{P}}^2}}$$

$$\beta_1^{\text{Thin}} = \frac{1 - 1 \cdot 0.011 - 0.351}{\sqrt{1^2 \cdot 0.011^2 \cdot 0.20^2 + (1 - 1 \cdot 0.011)^2 \cdot 0.20^2 + (0.351)^2 \cdot 0.05^2}},$$

$$\beta_1^{\text{Thin}} = 3.211$$

$$\beta_2^{\text{Thin}} = \frac{1 - D_{S_2} \cdot A_{rt} - SR_p^{\text{Thin}}}{\sqrt{D_{S_2}^2 \cdot A_{rt}^2 \cdot COV_{\Delta t}^2 + \left(1 - D_{S_2} \cdot A_{rt}\right)^2 \cdot COV_{S_f}^2 + \left(SR_p^{\text{Thin}}\right)^2 \cdot COV_{\text{P}}^2}}$$

$$\beta_2^{\text{Thin}} = \frac{1 - 2 \cdot 0.011 - 0.351}{\sqrt{2^2 \cdot 0.011^2 \cdot 0.20^2 + (1 - 2 \cdot 0.011)^2 \cdot 0.20^2 + (0.351)^2 \cdot 0.05^2}},$$

$$\beta_2^{\text{Thin}} = 3.190$$

$$\beta_3^{\text{Thin}} = \frac{1 - D_{S_3} \cdot A_{rt} - SR_p^{\text{Thin}}}{\sqrt{D_{S_3}^2 \cdot A_{rt}^2 \cdot COV_{\Delta t}^2 + \left(1 - D_{S_3} \cdot A_{rt}\right)^2 \cdot COV_{S_f}^2 + \left(SR_p^{\text{Thin}}\right)^2 \cdot COV_{\text{P}}^2}}.$$

$$\beta_3^{\text{Thin}} = \frac{1 - 4 \cdot 0.011 - 0.351}{\sqrt{4^2 \cdot 0.011^2 \cdot 0.20^2 + (1 - 4 \cdot 0.011)^2 \cdot 0.20^2 + (0.351)^2 \cdot 0.05}}.$$

$$\beta_3^{\text{Thin}} = 3.145$$

m. Step 14. Calculate the base DF for all components

The Φ in the formula below is the standard normal cumulative distribution function (NORMSDIST in Excel).

$$D_{fb}^{\text{Thin}} = \left[\frac{\left(Po_{p1}^{\text{Thin}}\,\Phi\left(-\beta_1^{\text{Thin}}\right)\right) + \left(Po_{p2}^{\text{Thin}}\,\Phi\left(-\beta_2^{\text{Thin}}\right)\right) + \left(Po_{p3}^{\text{Thin}}\,\Phi\left(-\beta_3^{\text{Thin}}\right)\right)}{1.56E - 04}\right]$$

$$D_{fb}^{\text{Thin}} = \left[\frac{\left(0.879\,\Phi(-3.211)\right) + \left(0.099\,\Phi(-3.190)\right) + \left(0.022\,\Phi(-3.145)\right)}{1.56E - 04}\right]$$

$$D_{fb}^{\text{Thin}} = 0.118$$

n. Step 15. Determine the DF for thinning

$$D_f^{\text{Thin}} = max\left[\left(\frac{D_{fB}^{\text{Thin}} \cdot F_{IP} \cdot F_{DL} \cdot F_{WD} \cdot F_{AM} \cdot F_{SM}}{F_{OM}}\right), 0.1\right]$$

$$D_f^{\text{Thin}} = max\left[\left(\frac{0.118 \cdot 3 \cdot 3 \cdot 1 \cdot 1 \cdot 1}{1}\right), 0.1\right]$$

$$D_f^{\text{Thin}} = 1.059$$

4. External Corrosion Damage Factor

1. Asset

Line/Tag Number	340-PG-1001-10-06S3
Type	Pipe 10"
Material	Carbon Steel ASTM A106 Gr B
Fluid Handle	C1-C2
From	Acid Gas Absorber (340-T-1001)
To	Sweet Gas KO Drum (340-D-1002)
Unit	AGRU - SRU
P&ID No.	MTDF-PR-340-PID-1002 MTDF-PR-340-PID-1009

2. Component Data

Starting Date	09/03/17
Last Inspection	24/09/22
Thickness (mm)	14,15
Corrosion Allowance (in)	0,118
Max. Design Temperature (°C)	204,4
Min. Design Temperature (°C)	-28,9
Max. Design Pressure (MPa)	10,2
Operating Temperature (°C)	30
Operating Pressure (MPa)	6,16
Design Code	ASME B31.3
Equipment Type	Pipe
Component Type	PIPE - 10
Diameter (in)	10
Component Geometry Data	CYL, ELB
Material Specification	ASTM A106 Gr B
Yield Strength (MPa)	240
Tensile Strength (MPa)	415
Allowable Stress (MPa)	138
Weld Joint Efficiency	1
Heat Tracing	No

3. Calculation

a. Step 1. Determine the furnished thickness

t	=	15.09	mm
age	=	6	years

b. Step 2. Determine the base corrosion rate

$C_{r,bm}$ = 0.025 mm/year

c. Step 3. Determine the final corrosion rate

$$C_r = C_{rB} \cdot max[F_{EQ}, F_{IF}]$$

$$C_r = 0.025 \cdot max[1, 1]$$
$$C_r = 0.025 \quad \text{mm/year}$$

d. Step 4. Determine the last inspection thickness reading and the time in-service since the last inspection

t_{rde} = 14.15 mm (Inspected on 24-09-2022)
age_{tk} = 1 years

e. Step 5. Determine the in-service time since the coating has been installed

$$\text{age}_{\text{coat}} = \text{Calculation Date} - \text{Coating Installation Date}$$
$$\text{age}_{\text{coat}} = 6 \text{ years}$$

f. Step 6. Determine coating adjustment
Coating quality

$$\text{Coat}_{adj} = min[5, \text{ age}_{\text{coat}}] - min[5, \text{age } e_{\text{coat}} - age_{tk}]$$

$$\text{Coat}_{adj} = min[5, 6] - min[5, 6 - 5]$$

$$\text{Coat}_{adj} = 0.1$$

g. Step 7. Determine the in-service time over which external corrosion may have occurred

$$\text{age} = \text{age}_{\text{tk}} - \text{Coat}_{adj}$$
$$\text{age} = 1 - 0.1$$
$$\text{age} = 0.9$$

h. Step 8. Determine the allowable stress (S), weld joint efficiency (E), and minimum required thickness (t_{min}).

S = 138 MPa
E = 1
t_{min} = 12.98 mm

i. Step 9. Determine A_{rt} parameter

$$A_{rt} = \frac{C_r \cdot age}{t_{rde}}$$

$$A_{rt} = \frac{0.025 \cdot 0.9}{14.15}$$
$$A_{rt} = 0.002$$

j. Step 10. Calculate the flow stress

$$FS^{\text{extcorr}} = \frac{(YS + TS)}{2} \cdot E \cdot 1.1$$
$$FS^{\text{extcorr}} = \frac{(240 + 415)}{2} \cdot 1 \cdot 1.1$$
$$FS^{\text{extcorr}} = 360.25$$

k. Step 11. Calculate the strength ratio parameter

$$SR_P^{\text{extcorr}} = \frac{S \cdot E}{FS^{\text{extcorr}}} \cdot \frac{\text{Max}(t_{min}, t_c)}{t_{rde}}$$
$$SR_P^{\text{extcorr}} = \frac{138 \cdot 1}{360.25} \cdot \frac{12.98}{14.15}$$
$$SR_P^{\text{extcorr}} = 0.351$$

l. Step 12. Determine the number of inspections $N_A^{\text{extcorr}}, N_B^{\text{extcorr}}, N_C^{\text{extcorr}}, N_D^{\text{extcorr}}$

$$N_A^{\text{Thin}} = 0$$
$$N_B^{\text{Thin}} = 0$$
$$N_C^{\text{Thin}} = 1$$
$$N_D^{\text{Thin}} = 0$$

m. Step 13. Calculate the inspection effectiveness factors
Prior Probability : High Confidence Data
Conditional Probability : C – Fairly Effective

$$I_1^{\text{extcorr}} = \text{Pr}_{p1}^{\text{extcorr}} \, . \left(\text{Co}_{p1}^{\text{extcorr}\ C}\right)^{N_C^{\text{extcorr}}}$$
$$I_1^{\text{extcorr}} = 0.8 \, . \, 0.5$$
$$I_1^{\text{extcorr}} = 0.4$$

$$I_2^{\text{extcorr}} = \text{Pr}_{p2}^{\text{extcorr}} \, . \left(\text{Co}_{p2}^{\text{extcorr}\ C}\right)^{N_C^{\text{extcorr}}}$$
$$I_2^{\text{extcorr}} = 0.15 \, . \, 0.3$$
$$I_2^{\text{extcorr}} = 0.045$$

$$I_3^{\text{extcorr}} = \text{Pr}_{p3}^{\text{extcorr}} \, . \left(\text{Co}_{p3}^{\text{extcorr}\ C}\right)^{N_C^{\text{extcorr}}}$$
$$I_3^{\text{extcorr}} = 0.05 \, . \, 0.2$$
$$I_3^{\text{extcorr}} = 0.01$$

n. Step 14. Calculate the posterior probabilities Po_{p1}^{extcorr}, Po_{p2}^{extcorr} and Po_{p3}^{extcorr}

$$Po_{p1}^{\text{extcorr}} = \frac{I_1^{\text{extcorr}}}{I_1^{\text{extcorr}} + I_2^{\text{extcorr}} + I_3^{\text{extcorr}}}$$
$$Po_{p1}^{\text{extcorr}} = \frac{0.4}{0.4 + 0.045 + 0.01}$$
$$Po_{p1}^{\text{extcorr}} = 0.879$$

$$Po_{p2}^{\text{extcorr}} = \frac{I_2^{\text{extcorr}}}{I_1^{\text{extcorr}} + I_2^{\text{extcorr}} + I_3^{\text{extcorr}}}$$
$$Po_{p2}^{\text{extcorr}} = \frac{0.045}{0.4 + 0.045 + 0.01}$$
$$Po_{p2}^{\text{extcorr}} = 0.099$$

$$Po_{p3}^{\text{extcorr}} = \frac{I_3^{\text{extcorr}}}{I_1^{\text{extcorr}} + I_2^{\text{extcorr}} + I_3^{\text{extcorr}}}$$
$$Po_{p3}^{\text{extcorr}} = \frac{0.01}{0.4 + 0.045 + 0.01}$$
$$Po_{p3}^{\text{extcorr}} = 0.022$$

o. Step 15. Calculate the parameters $\beta_1^{\text{Thin}}, \beta_2^{\text{Thin}}, \beta_3^{\text{Thin}}$ assigning $COV_{\Delta t} = 0.20, COV_{S_f} = 0.20$ and $COV_P = 0.05$. where $D_{S_1} = 1, D_{S_2} = 2$ and $D_{S_3} = 4$

The parameters $\beta_1^{\text{Thin}}, \beta_2^{\text{Thin}}, \beta_3^{\text{Thin}}$ are the reliability indices for each damage states 1, 2 and 3. The D_{S_1}, D_{S_2} and D_{S_3} are the corrosion rate factors for damage states 1, 2 and 3.

$$\beta_1^{\text{extcorr}} = \frac{1 - D_{S_1} \cdot A_{rt} - SR_p^{\text{extcorr}}}{\sqrt{D_{S_1}^2 \cdot A_{rt}^2 \cdot COV_{\Delta t}^2 + \left(1 - D_{S_1} \cdot A_{rt}\right)^2 \cdot COV_{S_f}^2 + \left(SR_p^{\text{extcorr}}\right)^2 \cdot COV_{\text{P}}^2}}$$
$$\beta_1^{\text{extcorr}} = \frac{1 - 1 \cdot 0.002 - 0.351}{\sqrt{1^2 \cdot 0.011^2 \cdot 0.20^2 + (1 - 1 \cdot 0.002)^2 \cdot 0.20^2 + (0.351)^2 \cdot 0.05^2}},$$
$$\beta_1^{\text{extcorr}} = 3.229$$

$$\beta_2^{\text{extcorr}} = \frac{1 - D_{S_2} \cdot A_{rt} - SR_p^{\text{extcorr}}}{\sqrt{D_{S_2}^2 \cdot A_{rt}^2 \cdot COV_{\Delta t}^2 + \left(1 - D_{S_2} \cdot A_{rt}\right)^2 \cdot COV_{S_f}^2 + \left(SR_p^{\text{extcorr}}\right)^2 \cdot COV_{\text{P}}^2}}$$
$$\beta_2^{\text{extcorr}} = \frac{1 - 2 \cdot 0.002 - 0.351}{\sqrt{2^2 \cdot 0.011^2 \cdot 0.20^2 + (1 - 2 \cdot 0.002)^2 \cdot 0.20^2 + (0.351)^2 \cdot 0.05^2}},$$
$$\beta_2^{\text{extcorr}} = 3.226$$

$$\beta_3^{\text{extcorr}} = \frac{1 - D_{S_3} \cdot A_{rt} - SR_p^{\text{extcorr}}}{\sqrt{D_{S_3}{}^2 \cdot A_{rt}{}^2 \cdot COV_{\Delta t}{}^2 + \left(1 - D_{S_3} \cdot A_{rt}\right)^2 \cdot COV_{S_f}{}^2 + \left(SR_p^{\text{Thin}}\right)^2 \cdot COV_{\text{P}}{}^2}}.$$

$$\beta_3^{\text{extcorr}} = \frac{1 - 4 \cdot 0.002 - 0.351}{\sqrt{4^2 \cdot 0.011^2 \cdot 0.20^2 + (1 - 4 \cdot 0.002)^2 \cdot 0.20^2 + (0.351)^2 \cdot 0.05^2}}.$$

$$\beta_3^{\text{extcorr}} = 3.221$$

p. Step 16. Determine the DF for external corrosion

The Φ in the formula below is the standard normal cumulative distribution function (NORMSDIST in Excel).

$$D_f^{\text{extcorr}} = \left[\frac{\left(Po_{p1}^{\text{extcorr}}\,\Phi(-\beta_1^{\text{extcorr}})\right) + \left(Po_{p2}^{\text{extcorr}}\,\Phi(-\beta_2^{\text{extcorr}})\right) + \left(Po_{p3}^{\text{extcorr}}\,\Phi(-\beta_3^{\text{extcorr}})\right)}{1.56E-04}\right]$$

$$D_f^{\text{extcorr}} = \left[\frac{\left(0.879\Phi(-3.229)\right) + \left(0.099\Phi(-3.226)\right) + \left(0.022\Phi(-3.221)\right)}{1.56E-04}\right]$$

$$D_f^{\text{extcorr}} = 0.092$$

4. Consequence of Failure

1. Asset

Line/Tag Number	340-PG-1001-10-06S3
Type	Pipe 10"
Material	Carbon Steel ASTM A106 Gr B
Fluid Handle	C1-C2
From	Acid Gas Absorber (340-T-1001)
To	Sweet Gas KO Drum (340-D-1002)
Unit	AGRU - SRU
P&ID No.	MTDF-PR-340-PID-1002 MTDF-PR-340-PID-1009

2. Determine the Representative Fluid and Associated Properties

Step 1. Select a representative fluid group

Table E. 3 Representative Fluid

Fluid	Fluid Type	Examples of Applicable Materials
C1-C2	TYPE 0	Methane, Ethane, Ethylene, LNG, Fuel Gas

Step 2. Determine the stored fluid phase

Fluid Phase = Gas

Step 3. Determine the stored fluid properties

For a stored vapor:

Molecular weight = 23

Ideal gas specific heat ratio = -0.0083

$C_p = 12.72 \text{ J/kmol} - \text{K}$

$$k = \frac{C_p}{C_p - R}$$

$$k = \frac{12.72}{12.72 - 1545}$$

$k = -0.0083$

Autoignition temperature = 1036 °F

Step 4. Determine the steady state phase of the fluid after release to the atm

Table E. 4 Final Phase of The Fluid After Release to The atm

Phase of Fluid at Normal Operating (Storage) Conditions	Phase of Fluid at Ambient (after release) Conditions	Determination of Final Phase of Consequence Calculation
Gas	Gas	Model as gas

3. **Release Hole Size Selection**
Step 1. Determine the release hole size diameters
Component Diameter = 10 inch

Table E. 5 Release Hole Size

Release Hole Number	Release Hole Size	Diameters (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 to 0.25	$d_1 = 0.25$
2	Medium	> 0.25 - 2	$d_2 = 1$
3	Large	> 2 - 6	$d_3 = 4$
4	Rupture	> 6	$d_4 = 8$

Step 2. Determine the generic failure frequency
Equipment Type = Pipe
Component Type = PIPE-10

Table E. 6 The Generic Failure Frequency

GFF As a Function of Hole Size (failures/yr)				(failures/yr)
Small	Medium	Large	Rupture	
8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05

4. **Release Rate Calculation**
Step 1. Determine the fluid phase
Fluid phase = Gas

Step 2. Calculate the release hole size area

$$A_n = \frac{\pi d_n^2}{4}$$

Table E. 7 The Release Hole Size Area

Small	Medium	Large	Rupture
0.049 in^2	0.785 in^2	12.56 in^2	50.256 in^2

Step 3. Viscosity correction factor
$K_{v,n} = 1$ (conservative assumption)

Step 4. Calculate the release rate for each release area
$C_d = 0.9$

$$W_n = \frac{C_d}{C_2} \cdot A_n \cdot P_s \sqrt{\left(\frac{k \cdot MW \cdot g_c}{R \cdot T_s}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Table E. 8 The Release Rate for Each Release Area

Small	Medium	Large	Rupture
1.864 lb/s	29.824 lb/s	477.182 lb/s	1908.726 lb/s

5. **Estimate the Fluid Inventory Available for Release**
Step 1. Group comp. and eq. items into inventory groups
Equipment Type = Pipe 100 % full, calculated for Level 2 methodology

Step 2. Determine the fluid mass

$\text{mass}_{\text{comp}} = 150 \text{ kg} = 330.693 \text{ lb}$

Step 3. Determine the fluid mass in each of the other components in the inventory group

$\text{mass}_{\text{comp,i}} = 25000 \text{ kg} = 55115.566 \text{ lb}$

Step 4. Determine the fluid mass in the inventory group

$\text{mass}_{\text{inv}} = 25000 \text{ kg} = 55115.566 \text{ lb}$

Step 5. Calculate the flow rate a 203 mm (8 in) diameter hole

$$W_n = \frac{C_d}{C_2} \cdot A_n \cdot P_s \sqrt{\left(\frac{k \cdot MW \cdot g_c}{R \cdot T_s}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

$W_8 = 1908.726 \text{ lb/s}$

Step 6. For each release hole size, calculate the added fluid mass

Added fluid mass is the remaining fluid mass left behind when there is a leak and all safety valves have been closed. In the calculation, the time limit is 180 seconds or 3 minutes and then multiplied by the fluid mass in the system which is the minimum either from hole size n or from a maximum hole size of 8 inches.

$$\text{mass}_{add,n} = 180 \cdot min[W_n, W_{max8}]$$

Table E. 9 The Added Fluid Mass

Small	Medium	Large	Rupture
335.52 lb	5368.99 lb	85892.69 lb	343570.75 lb

Step 7. For each release hole size, calculate the available mass

In this calculation stage, the maximum mass available for release will be calculated. Based on the formula, the mass released is the minimum among the masses contained in the equipment plus added mass and mass in one group inventory.

$$\text{mass}_{\text{avail},n} = min[\{\text{mass}_{\text{comp}} + \text{mass}_{\text{add},n}\}, \text{mass}_{\text{inv}}]$$

Table E. 10 The Available Mass

Small	Medium	Large	Rupture
666.21 lb	5698.99 lb	55115.57 lb	55116 lb

6. **Determine the Release Type (Continuous or Instantaneous)**
   Step 1. Determine release type is instantaneous or continuous

   If the release mass ($\text{mass}_{\text{avail},n}$) is greater than 10,000 lbs in 180 seconds, then the release is instantaneous; otherwise, the release is continuous. Determination of leakage time interval by 180 seconds based on the calculation of maximum available for release carried out in the previous stage.

Small	Medium	Large	Rupture
Continuous Release	Continuous Release	Instantaneous Release	Instantaneous Release

7. **Assess the Impact of Detection and Isolation Systems**
   Step 1. Detection and isolation systems present in the unit

Table E. 11 Type of Detection System

Type of Detection System	Detection Classification
Visual detection, cameras, or detectors with marginal coverage.	C

Table E. 12 Type of Detection System

Type of Isolation System	Isolation Classification
Isolation or shutdown systems activated by operators in the control room or other suitable location remote from the leak.	B

Step 2. The release reduction factor

Table E. 13 The Release Reduction Factor

System Classifications		Release Magnitude Adjustment	Reduction Factor
Detection	Isolation		
C	B	No adjustment to release rate or mass	0.00

Step 3. The total leak durations

Table E. 14 The Total Leak Durations

System Classifications		Maximum Leak Duration, ld_{max}
Detection	Isolation	
C	B	1 hour for 1/4 inch leaks
		40 minutes for 1 inch leaks
		20 minutes for 4 inch leaks

8. **Determine the Release Rate and Mass for COF**
   Step 1. Calculate the adjusted release rate

$$\text{rate}_n = W_n(1 - \text{fact}_{di})$$

Table E. 15 The Adjusted Release Rate

Small	Medium	Large	Rupture
1.864 lb/s	29.824 lb/s	477.182 lb/s	1908.726 lb/s

Step 2. Calculate the leak duration

$$ld_n = min\left[\left\{\frac{\text{mass}_{\text{avail},n}}{\text{rate}_n}\right\}, \{60 \cdot ld_{max,n}\}\right]$$

Table E. 16 The Leak Duration

Small	Medium	Large	Rupture
60 min	40 min	20 min	1 min

Step 3. Calculate the release mass

$$\text{mass}_n = min[\{\text{rate}_n \cdot ld_n\}, \text{mass}_{\text{avail},n}]$$

Table E. 17 The Release Mass

Small	Medium	Large	Rupture
666.212 lb	5698.986 lb	55115.56 lb	55115.57 lb

9. Determine Flammable and Explosive Consequence

Step 1. Select the consequence area mitigation reduction factor

Table E. 18 The Mitigation Reduction Factor

Mitigation System	Consequence Area Adjustment	Reduction Factor
Foam Spray System	Reduce consequence area by 15%	0.15

Step 2. Determine the fluid type

A. Component Damage

Table E. 19 Component Damage Continuous Release Constants

Fluid	Continuous Releases Constants							
	Autoignition Not Likely (AINL-CONT)				Autoignition Likely (AIL-CONT)			
	Gas		Liquid		Gas		Liquid	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
C1-C2	43.0	0.98	-----	-----	280.0	0.950	----	----

Table E. 20 Component Damage Instantaneous Release Constants

Fluid	Instantaneous Releases Constants							
	Autoignition Not Likely (AINL-INST)				Autoignition Likely (AIL-INST)			
	Gas		Liquid		Gas		Liquid	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
C1-C2	41.0	0.67	-----	-----	1079	0.62	-----	-----

B. Personnel Injury

Table E. 21 Comp. Damage Continuous and Instantaneous Release Constants

Fluid	Continuous Releases Constants							
	Autoignition Not Likely (AINL-CONT)				Autoignition Likely (AIL-CONT)			
	Gas		Liquid		Gas		Liquid	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
C1-C2	110.0	0.96	-----	-----	745.0	0.92	-----	-----
	Instantaneous Releases Constants							

	Autoignition Not Likely (AINL-INST)				Autoignition Likely (AIL-INST)			
	Gas		Liquid		Gas		Liquid	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
	79.0	0.67	-----	-----	3100	0.63	-----	-----

Step 3. The component damage for Autoignition Not Likely

$CA_n^{CONT} = a(\text{ rate }_n)^b$

$CA_n^{INST} = a(\text{ mass }_n)^b$

Table E. 22 The Component Damage for AINL

Small	Medium	Large	Rupture
79.160 lb/s	1198.232 lb/s	18137.544 lb/s	61580 lb/s

Step 4. The component damage for Autoignition Likely

$CA_n^{CONT} = a(\text{ rate }_n)^b$

$CA_n^{INST} = a(\text{ mass }_n)^b$

Table E. 23 The Component Damage for AIL

Small	Medium	Large	Rupture
505.917 lb/s	7046.826 lb/s	98153.895 lb/s	938883 lb/s

Step 5. The personnel injury for Autoignition Not Likely

$CA_n^{CONT} = a(\text{ rate }_n)^b$

$CA_n^{INST} = a(\text{ mass }_n)^b$

Table E. 24 The Personnel Injury for AINL

Small	Medium	Large	Rupture
199.995 lb/s	2864.005 lb/s	41013.707 lb/s	118654 lb/s

Step 6. The personnel injury for Autoignition Likely

$CA_n^{CONT} = a(\text{ rate }_n)^b$

$CA_n^{INST} = a(\text{ mass }_n)^b$

Table E. 25 The Personnel Injury for AIL

Small	Medium	Large	Rupture
1321.118 lb/s	16933.818 lb/s	217042.742 lb/s	3008600.2 lb/s

Step 7. The component damage consequence area for Autoignition Not Likely

$CA_{cmd} = a(\text{ rate }_n)^b \cdot (1 - \text{ fact }_{\text{mit}})$ continuous

$CA_{cmd} = a(\text{ mass }_n)^b \cdot \left(\frac{1 - \text{fact}_{\text{mit}}}{\text{eneff}_n}\right)$ instantaneous

Table E. 26 The Component Damage CA for AINL

Small	Medium	Large	Rupture
67.286 ft²	1018.497 ft²	2887.748 ft²	9804.340 ft²

Step 8. The component damage consequence area for Autoignition Likely

$CA_{cmd} = a(\text{ rate }_{n})^{b} \cdot (1 - \text{ fact }_{\text{mit}})$ continuous

$CA_{cmd} = a(\text{ mass }_{n})^{b} \cdot \left(\frac{1-\text{ fact }_{\text{mit}}}{\text{eneff }_{n}}\right)$ instantaneous

Table E. 27 The Component Damage for AIL

Small	Medium	Large	Rupture
430.030 ft²	5989.802 ft²	15627.460 ft²	149483.18 ft²

Step 9. The personnel injury consequence area for Autoignition Not Likely

$CA_{\text{inj}} = a(\text{ rate }_{n})^{b} \cdot (1 - \text{ fact }_{\text{mit}})$ continuous

$CA_{inj} = a(\text{ mass }_{n})^{b} \cdot \left(\frac{1-\text{ fact }_{\text{mit}}}{\text{eneff }_{n}}\right)$ instantaneous

Table E. 28 The Personnel Injury CA for AINL

Small	Medium	Large	Rupture
169.996 ft²	2434.405 ft²	6529.950 ft²	18891.294 ft²

Step 10. The personnel injury consequence area for Autoignition Likely

$CA_{\text{inj}} = a(\text{ rate }_{n})^{b} \cdot (1 - \text{ fact }_{\text{mit}})$ continuous

$CA_{inj} = a(\text{ mass }_{n})^{b} \cdot \left(\frac{1-\text{ fact }_{\text{mit}}}{\text{eneff }_{n}}\right)$ instantaneous

Table E. 29 The Personnel Injury CA for AIL

Small	Medium	Large	Rupture
1123.009 ft²	14393.745 ft²	34556.21 ft²	479019.83 ft²

Step 11. Calculate the instantaneous/continuous blending factor

$\text{fact}_{n}^{IC} = min\left[\left\{\frac{\text{rate }_{n}}{C_5}\right\}, 1.0\right]$ where C5 = 25.2 kg/s or 55.6 lbs

Table E. 30 The Instantaneous/Continuous Blending Factor

Small	Medium	Large	Rupture
0.0335	10.536	1.0	1.0

Step 13. Calculate the AIT blending factor, fact ^{AIT}

$\text{fact}^{AIT} = 0$ for $T_s + C_6 \leq AIT$

$\text{fact}^{AIT} = \frac{(T_s - AIT + C_6)}{2 \cdot C_6}$ for $T_s + C_6 > AIT > T_s - C_6$

$\text{fact}^{AIT} = 1$ for $T_s - C_6 \geq AIT$

where C6 = 55.6 K

$T_S = 30\text{C} \quad AIT = 1036\text{ F} = 557.778\text{ C} \quad C_6 = 55.6\text{K} = -217.55\text{C}$

$\text{fact}^{AIT} = 0$

Step 14. Calculate the continuous/instantaneous blended consequence areas

a. Blended consequence area of component damage – Auto Ignition Not Likely

$$CA_{cmd,n}^{AINL} = CA_{cmd,n}^{AIN-INST} \cdot fact_n^{IC} + CA_{cmd,n}^{AINL-CONT} \cdot (1 - fact_n^{IC})$$

Table E. 31 Blended Consequence Area of Component Damage – AINL

Small	Medium	Large	Rupture
65.030 ft²	472.175 ft²	2887.748 ft²	9804.342 ft²

b. Blended consequence area of component damage – Auto Ignition Likely

$$CA_{cmd,n}^{AIL} = CA_{cmd,n}^{AIL-INST} \cdot fact_n^{IC} + CA_{cmd,n}^{AIL-CONT} \cdot (1 - fact_n^{IC})$$

Table E. 32 Blended Consequence Area of Component Damage – ANL

Small	Medium	Large	Rupture
415.613 ft²	2776.871 ft²	15627.46 ft²	149483.18 ft²

c. Blended consequence area of personnel injury – Auto Ignition Not Likely

$$CA_{inj,n}^{AINL} = CA_{inj,n}^{AINL-INST} \cdot fact_n^{IC} + CA_{inj,n}^{AINL-CONT} \cdot (1 - fact_n^{IC})$$

Table E. 33 Blended Consequence Area of Personnel Injury – AINL

Small	Medium	Large	Rupture
164.296 ft²	1128.590 ft²	6529.950 ft²	18891.294 ft²

d. Blended consequence area of personnel injury – Auto Ignition Likely

$$CA_{inj,n}^{AIL} = CA_{inj,n}^{AIL-INST} \cdot fact_n^{IC} + CA_{inj,n}^{AIL-CONT} \cdot (1 - fact_n^{IC})$$

Table E. 34 Blended Consequence Area of Personnel Injury – AIL

Small	Medium	Large	Rupture
1085.361 ft²	6672.938 ft²	34556.211 ft²	479010.83 ft²

Step 15. Calculate the AIT blended consequence areas

a. Flammable consequence area of component damage

$$CA_{cmd,n}^{fam} = CA_{cmd,n}^{AIL} \cdot fact^{AIT} + CA_{cmd,n}^{AINL} \cdot (1 - fact^{AIT})$$

Table E. 35 Flammable Consequence Area of Component Damage

Small	Medium	Large	Rupture
65.030 ft²	472.175 ft²	2887.748 ft²	9804.342 ft²

b. Flammable consequence area of personnel injury

$$CA_{inj,n}^{fam} = CA_{inj,n}^{flam-ALL} \cdot fact^{AIT} + CA_{inj,n}^{AINL} \cdot (1 - fact^{AIT})$$

Table E. 36 Flammable Consequence Area of Personnel injury

Small	Medium	Large	Rupture
164.296 ft²	1128.590 ft²	6529.950 ft²	18891.294 ft²

Step 16. Determine the final consequence areas

Equipment Type : Pipe
Diameter : 10 inches
Component Type : PIPE – 10

Based on the type of component above, the gff value for each hole size (failures / year) is as follows.

gff 1(small) = 8.00E-06
gff 2 (medium) = 2.00E-05
gff 3 (large) = 2.00E-06
gff 4 (rupture) = 6.00E-07

gfftotal = 3.06E-05

Flammable Consequence Area of Component Damage

$$CA_{cmd}^{flam} = \left(\frac{\sum_{n=1}^{4} gff_n \cdot CA_{cmd,n}^{flam}}{gff_{total}} \right)$$

$$= \left(\frac{(8.00\text{E}-06 \cdot 65.030) + (2.00\text{E}-05 \cdot 472.175) + (2.00\text{E}-06 \cdot 2887.748) + (6.00\text{E}-07 \cdot 9804.342))}{3.06\text{E}-05} \right)$$

$$= 706.596 \text{ ft}^2$$

Flammable Consequence Area of Personnel Injury

$$CA_{inj}^{flam} = \left(\frac{\sum_{n=1}^{4} gff_n \cdot CA_{inj,n}^{flam}}{gff_{\text{total}}} \right) = 1577.805 \text{ ft}^2$$

$$= \left(\frac{(8.00\text{E}-06 \cdot 164.3) + (2.00\text{E}-05 \cdot 1128.6) + (2.00\text{E}-06 \cdot 6529.95) + (6.00\text{E}-07 \cdot 18891.3))}{3.06\text{E}-05} \right)$$

$$= 1577.805 \text{ ft}^2$$

10. Determine Toxic Consequence

There are no toxic chemicals release

$$CA_{\text{inj}}^{tox} = \left(\frac{\sum gff_n \cdot CA_{\text{inj.n}}^{tox}}{gff_{\text{total}}} \right) = 0.00\text{E}+00 \text{ ft}^2$$

11. Determine Nonflammable, Nontoxic Consequence

There are no steam, caustic, or acid releases in the equipment

$$CA_{\text{inj}}^{nfnt} = \left(\frac{\sum gff_n \cdot CA_{\text{inj.n}}^{\text{leak}}}{gff_{\text{total}}} \right) = 0.00\text{E} + 00 \text{ ft}^2$$

12. Determine the Final Consequence Area

Step 1. Calculate the final component damage consequence area

$$CA_{f,cmd} = CA_{cmd}^{flam} = 706.596 \text{ ft}^2$$

Step 2. Calculate the final personnel injury consequence area

$$CA_{\text{inj}} = max\left[CA_{inj}^{flam}, CA_{inj}^{tox}, CA_{inj}^{nfnt}\right]$$

$$CA_{\text{inj}} = max[1577.805 \text{ ft}^2, 0, 0] = 1577.805 \text{ ft}^2$$

Step 3. Final Consequence Area

$$CA = max\left[CA_{cmd}, CA_{inj}\right]$$

$$CA = max[706.596 \text{ ft}^2, 1577.805 \text{ ft}^2]$$

$$CA = 1577.805 \text{ ft}^2$$

COF Category = C – Moderate

5. Result

1. Asset

Line/Tag Number	340-PG-1001-10-06S3
Type	Pipe 10"
Material	Carbon Steel ASTM A106 Gr B
Fluid Handle	C1-C2
From	Acid Gas Absorber (340-T-1001)
To	Sweet Gas KO Drum (340-D-1002)
Unit	AGRU - SRU
P&ID No.	MTDF-PR-340-PID-1002 MTDF-PR-340-PID-1009

2. Risk Analysis

a. Probability of Failure (POF)

- Total Damage Factor
  $D_{f-\text{total}} = 1.150$

- POF Score
  $P_f(\text{t}) = 3.52\text{E} - 05$

- Category
  2 - Unlikely

- Selected Damage Factors
  Thinning, External Corrosion

b. Consequence of failure (COF)

- Representative Fluid
  C1-C2

- Fluid Phase
  Gas

- COF Score
  $CA_f = 1577.8052 \text{ ft}^2$

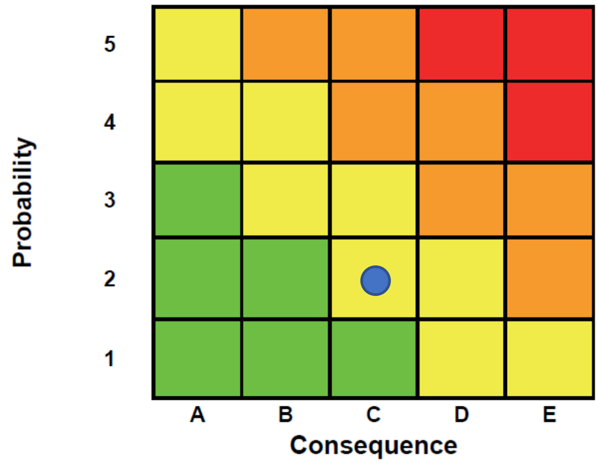
- Category
  C - Moderate

c. Risk Ranking

- Risk Score
  $\text{R(t)} = 0.05550 \text{ ft}^2/\text{year}$
  $= 0.00547 \text{ m}^2/\text{year}$

- Risk Level

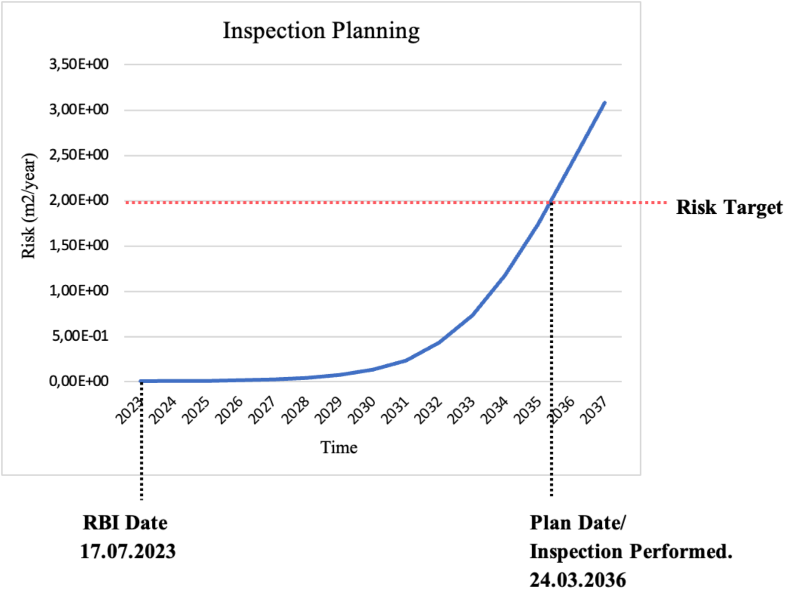
2C - Medium



3. Inspection Planning

INSPECTION PLANNING						
Year	**Dfthin**	**Dfextcorr**	**POF Score**	**COF Score**	**Risk Score (ft^2/yr)**	**Risk Score (m^2/yr)**
2023	1,059	0,091	3,52E-05	1577,805	5,55E-02	5,16E-03
2024	1,487	0,095	4,84E-05	1577,805	7,64E-02	7,10E-03
2025	2,192	0,099	7,01E-05	1577,805	1,11E-01	1,03E-02
2026	3,397	0,104	1,07E-04	1577,805	1,69E-01	1,57E-02
2027	5,533	0,109	1,73E-04	1577,805	2,72E-01	2,53E-02
2028	9,425	0,115	2,92E-04	1577,805	4,61E-01	4,28E-02
2029	16,638	0,121	5,13E-04	1577,805	8,09E-01	7,52E-02
2030	30,008	0,127	9,22E-04	1577,805	1,45E+00	1,35E-01
2031	52,245	0,134	1,60E-03	1577,805	2,53E+00	2,35E-01
2032	96,139	0,142	2,95E-03	1577,805	4,65E+00	4,32E-01
2033	163,408	0,150	5,00E-03	1577,805	7,90E+00	7,34E-01
2034	261,171	0,159	8,00E-03	1577,805	1,26E+01	1,17E+00
2035	388,714	0,168	1,19E-02	1577,805	1,88E+01	1,74E+00
2036	535,936	0,178	1,64E-02	1577,805	2,59E+01	2,40E+00
2037	686,915	0,189	2,10E-02	1577,805	3,32E+01	3,08E+00

2035	388,714	0,168	1,19E-02	1577,805	1,88E+01	1,74E+00
2036*	460,785	0,173	1,41E-02	1577,805	2,23E+01	**2,07E+00**
2036**	535,936	0,178	1,64E-02	1577,805	2,59E+01	2,40E+00
2037	686,915	0,189	2,10E-02	1577,805	3,32E+01	3,08E+00



- Last Inspection Date = 24-09-2022
- Last Inspection Effectiveness Rating = C (Thinning and External Corrosion)
- Risk Target = 21.528 ft^2/year or 2 m^2/year
- Plan Date = 24-03-2036
- Inspection Recommendations

Table E. 37 Future Inspection Recommendations

No.	Damage Factor	Intrusive	Non-Intrusive
1	Thinning	For the total surface area: >5% visual examination AND >5% of the spot ultrasonic thickness measurements.	For the total surface area: >50% spot UT or random UT scans (automated or manual) OR random profile radiography of the selected area(s)
2	External Corrosion	Visual inspection of >30% of the exposed surface area with follow-up by UT, RT or pit gauge as required	

APPENDIX F – WEB APPS CODING

```php
<?php

include_once(__DIR__ . "/../include/dbcommon.php");
$componentData = DB::Query("SELECT * FROM component_data WHERE equipment_id
 = " . $data['equipment_id'])->fetchAssoc();
$preDfData = DB::Query("SELECT * FROM predf_thinning WHERE equipment_id = "
 . $data['equipment_id'])->fetchAssoc();

if (!function_exists('NORMDIST')) {
  function NORMSDIST($x, $mean = 0, $stddev = 0.953531, $precision = 48)
  {
    $result = 0;
    $x -= $mean;
    $x /= $stddev;
    for ($i = 0, $k = 1; $i < $precision; $i++) {
      $n = $i * 2 + 1;
      $k *= $n;
      $p = pow($x, $n) / $k;
      if (is_nan($p) || is_infinite($p)) break;
      $result += $p;
    }
    $result *= 1 / sqrt(2 * pi()) * exp(-pow($x, 2) / 2);
    $result += 0.5;
    return max(0, $result);
  };
};

// def variable from another table
$data['vh'] = $componentData['yield_strength'];
$data['vi'] = $componentData['tensile_strength'];
$data['vj'] = $componentData['weld_joint_efficiency'];
$data['vk'] = $componentData['allowable_stress'];

$data['vl'] = $preDfData['on_line_monitoring'];
if ($data['vl'] == 1) $data['vl'] = 2;
else $data['vl'] = 1;
```

```
$data['vm'] = $preDfData['injection_mix_points'];
if ($data['vm'] == 1) $data['vm'] = 3;
else $data['vm'] = 1;

$data['vn'] = $preDfData['dead_legs_segmen'];
if ($data['vn'] == 1) $data['vn'] = 3;
else $data['vn'] = 1;

$data['vo'] = $preDfData['welded_construction'];
if ($data['vo'] == 1) $data['vo'] = 1;
else $data['vo'] = 10;

$data['vp'] = $preDfData['ast_maintenance'];
if ($data['vp'] == 1) $data['vp'] = 1;
else $data['vp'] = 5;

$data['vq'] = $preDfData['ast_bottoms_settlement'];
if ($data['vq'] == 1) $data['vq'] = 2;
else $data['vq'] = 1;

// calculation
$data['c'] = ($data['a'] - $data['d']) / $data['b'];
$data['e'] = $preDfData["time_in_service_since_last_insp"];
$data['g'] = ($data['c'] * $data['e']) / $data['d'];
$data['h'] = (($data['vh'] + $data['vi']) / 2) * $data['vj'] * 1.1;
$data['i'] = ($data['vk'] * $data['vj'] * $data['f']) / ($data['h'] * $data
['d']);
$data['n'] = 0.80;
$data['o'] = 0.15;
$data['p'] = 0.05;
$data['q'] = $data['n'] * (0.9 ** $data['j']) * (0.7 ** $data['k']) * (0.5
** $data['l']) * (0.4 ** $data['m']);
$data['r'] = $data['o'] * (0.09 ** $data['j']) * (0.2 ** $data['k']) * (0.3
 ** $data['l']) * (0.33 ** $data['m']);
$data['s'] = $data['p'] * (0.01 ** $data['j']) * (0.1 ** $data['k']) * (0.2
 ** $data['l']) * (0.27 ** $data['m']);
```

```
$data['t'] = $data['q'] / ($data['q'] + $data['r'] + $data['s']);

$data['u'] = $data['r'] / ($data['q'] + $data['r'] + $data['s']);

$data['v'] = $data['s'] / ($data['q'] + $data['r'] + $data['s']);

$data['w'] = 0.2;

$data['x'] = 0.2;

$data['y'] = 0.05;

$data['z'] = 1;

$data['va'] = 2;

$data['vb'] = 4;

$data['vc'] = ((1 - $data['z'] * $data['g'] - $data['i']) / SQRT(($data['z'
] ** 2) * ($data['g'] ** 2) * ($data['w'] ** 2) + ((1 - $data['z'] * $data[
'g']) ** 2) * ($data['x'] ** 2) + ($data['i'] ** 2) * ($data['y'] ** 2)));

$data['vd'] = ((1 - $data['va'] * $data['g'] - $data['i']) / SQRT(($data['v
a'] ** 2) * ($data['g'] ** 2) * ($data['w'] ** 2) + ((1 - $data['va'] * $da
ta['g']) ** 2) * ($data['x'] ** 2) + ($data['i'] ** 2) * ($data['y'] ** 2))
);

$data['ve'] = ((1 - $data['vb'] * $data['g'] - $data['i']) / SQRT(($data['v
a'] ** 2) * ($data['g'] ** 2) * ($data['w'] ** 2) + ((1 - $data['vb'] * $da
ta['g']) ** 2) * ($data['x'] ** 2) + ($data['i'] ** 2) * ($data['y'] ** 2))
);

//$data['vf'] = 0.118;

$data['vf'] = (($data['t'] * NORMSDIST(0 - $data['vc'])) + ($data['u'] * NO
RMSDIST(0 - $data['vD'])) + ($data['v'] * NORMSDIST(0 - $data['ve'])) / (1.
56 * (10 ** (-4))));


$data['vg'] = MAX((($data['vf'] * $data['vm'] * $data['vn'] * $data['vo'] *
 $data['vp'] * $data['vq']) / $data['vl']), 0.1);
```

```php
<?php


include_once(__DIR__ . "/../include/dbcommon.php");
$componentData = DB::Query("SELECT * FROM component_data WHERE equipment_id
 = " . $data['equipment_id'])->fetchAssoc();
$preDfThinning = DB::Query("SELECT * FROM predf_thinning WHERE equipment_id
 = " . $data['equipment_id'])->fetchAssoc();
$preDfExternalCorrosion = DB::Query("SELECT * FROM predf_external_corrosion
 WHERE equipment_id = " . $data['equipment_id'])->fetchAssoc();


if (!function_exists('NORMDIST')) {
  function NORMSDIST($x, $mean = 0, $stddev = 1.0, $precision = 48)
  {
    $result = 0;
    $x -= $mean;
    $x /= $stddev;
    for ($i = 0, $k = 1; $i < $precision; $i++) {
      $n = $i * 2 + 1;
      $k *= $n;
      $p = pow($x, $n) / $k;
      if (is_nan($p) || is_infinite($p)) break;
      $result += $p;
    }
    $result *= 1 / sqrt(2 * pi()) * exp(-pow($x, 2) / 2);
    $result += 0.5;
    return max(0, $result);
  };
};


// def variable from another table
$data['vh'] = $componentData['yield_strength'];
$data['vi'] = $componentData['tensile_strength'];
$data['vj'] = $componentData['weld_joint_efficiency'];
$data['vk'] = $componentData['allowable_stress'];
$data['e'] = $preDfThinning['time_in_service_since_last_insp'];
$data['vt'] = $preDfExternalCorrosion['the_in_service_time'];
```

```
$ageTk = $data['vt'] - $data['e'];


$data['vs'] = $data['vr'];
$data['vu'] = doubleval(5 . "." . $data['vt']) - doubleval(5 . ".$ageTk");
$data['vv'] = $data['e'] - $data['vu'];
$data['vw'] = $data['vs'] * ($data['e'] / $data['d']);
$data['vx'] = (($data['vh'] + $data['vi']) / 2) * $data['vj'] * 1.1;
$data['vy'] = ($data['vk'] * $data['vj'] / $data['vx']) * ($data['f'] / $da
ta['d']);
$data['vz'] = 0.80;
$data['vva'] = 0.15;
$data['vvb'] = 0.05;
$data['vvc'] = $data['vz'] * (0.9 ** $data['j']) * (0.7 ** $data['k']) * (0
.5 ** $data['l']) * (0.4 ** $data['m']);
$data['vvd'] = $data['vva'] * (0.09 ** $data['j']) * (0.2 ** $data['k']) *
(0.3 ** $data['l']) * (0.33 ** $data['m']);
$data['vve'] = $data['vvb'] * (0.01 ** $data['j']) * (0.1 ** $data['k']) *
(0.2 ** $data['l']) * (0.27 ** $data['m']);
$data['vvf'] = $data['vvc'] / ($data['vvc'] + $data['vvd'] + $data['vve']);
$data['vvg'] = $data['vvd'] / ($data['vvc'] + $data['vvd'] + $data['vve']);
$data['vvh'] = $data['vve'] / ($data['vvc'] + $data['vvd'] + $data['vve']);
$data['vvi'] = 0.2;
$data['vvj'] = 0.2;
$data['vvk'] = 0.05;
$data['vvl'] = 1;
$data['vvm'] = 2;
$data['vvn'] = 4;
$data['vvo'] = ((1 - ($data['vvl'] * $data['vw']) - $data['vy']) / SQRT(($d
ata['vvl'] ** 2) * ($data['vw'] ** 2) * ($data['vvi'] ** 2) + ((1 - $data['
vvl'] * $data['vw']) ** 2) * ($data['vvj'] ** 2) + ($data['vy'] ** 2) * ($d
ata['vvk'] ** 2)));
$data['vvp'] = ((1 - $data['vvm'] * $data['vw'] - $data['vy']) / SQRT(($dat
a['vvm'] ** 2) * ($data['vw'] ** 2) * ($data['vvi'] ** 2) + ((1 - $data['vv
m'] * $data['vw']) ** 2) * ($data['vvj'] ** 2) + ($data['vy'] ** 2) * ($dat
a['vvk'] ** 2)));
$data['vvq'] = ((1 - $data['vvn'] * $data['vw'] - $data['vy']) / SQRT(($dat
a['vvn'] ** 2) * ($data['vw'] ** 2) * ($data['vvi'] ** 2) + ((1 - $data['vv
n'] * $data['vw']) ** 2) * ($data['vvj'] ** 2) + ($data['vy'] ** 2) * ($dat
a['vvk'] ** 2)));
```

```
$data['vvr'] = (($data['vvf'] * NORMSDIST(-$data['vvo'])) + ($data['vvg'] *
 NORMSDIST(-$data['vvp'])) + ($data['vvh'] * NORMSDIST(-$data['vvq'])) / (1
.56 * (10 ** (-4))));
```

```
<?php


include_once(__DIR__ . "/../include/dbcommon.php");

include_once("df_thinning_fn.php");

include_once("df_external_corrosion_fn.php");


$dfThinning = dfThinning($data['equipment_id']);

$dfExternalCorrosion = dfExternalCorrosion($data['equipment_id']);


$componentTypeId = DB::DBLookup("SELECT component_type FROM component_data
WHERE equipment_id = " . $data['equipment_id']);

$gff = DB::DBLookup("SELECT gff FROM component_data_type WHERE id = $compon
entTypeId");

$totalDf = $dfThinning + $dfExternalCorrosion;

$pofScore = $gff * $totalDf * 1;


if (!function_exists('getRiskDescription')) {

  function getRiskDescription($pof, $totalDF)

  {

    switch (true) {

      case ($pof < 0.0000306 && $totalDF <= 1):

        return "1 - Very Unlikely";

      case ($pof > 0.0000306 && $pof < 0.000306 && $totalDF > 1 && $totalDF
 <= 10):

        return "2 - Unlikely";

      case ($pof > 0.000306 && $pof < 0.00306 && $totalDF > 10 && $totalDF
<= 100):

        return "3 - Possible";

      case ($pof > 0.00306 && $pof < 0.0306 && $totalDF > 100 && $totalDF <
= 1000):

        return "4 - Likely";

      case ($pof > 0.0306 && $totalDF > 1000):

        return "5 - Very Likely";

      default:
```

```
        return "Unknown";
    }
  };
};

$data['explanation'] = "
To get the value of POF, we can multiply Total Generic Failure Frequency (g
ff), Total Damage Factor (Dftotal), and Management System Factor (FMS).
";

$pofCategory = getRiskDescription($pofScore, $totalDf);

$data['pof_score'] = sprintf('%.2E', $pofScore);
$data['pof_category'] = $pofCategory;
<?php

echo "<style>
span[id^='edit'] {
  color: red !important;
}
</style>";

include_once(__DIR__ . "/../include/dbcommon.php");

// variable definition
$data['model_release'] = 'Gas';

$data['h'] = ($data['g'] - 32) * (4 / 9);
$data['i'] = $data['b'] + ($data['c'] * $data['g']) + ($data['d'] * ($data[
'g'] ** 2)) + ($data['e'] * ($data['g'] ** 3));
$data['j'] = 0.25;
$data['k'] = 1;
$data['l'] = 4;
$data['m'] = 8;
$data['n'] = $data['i'] / ($data['i'] - 1545);
$data['o'] = 0.9;
$data['q'] = PI() * ($data['j'] / 2) ** 2;
```

```
$data['r'] = PI() * ($data['k'] / 2) ** 2;

$data['s'] = PI() * ($data['l'] / 2) ** 2;

$data['t'] = PI() * ($data['m'] / 2) ** 2;

$data['u'] = ($data['o'] / 1) * $data['q'] * $data['p'] * SQRT(($data['n']
* $data['a'] * 32) / (1545 * $data['h']) * (2 / ($data['n'] + 1)) ** (($dat
a['n'] + 1) / ($data['n'] - 1)));

$data['v'] = ($data['o'] / 1) * $data['r'] * $data['p'] * SQRT(($data['n']
* $data['a'] * 32) / (1545 * $data['h']) * (2 / ($data['n'] + 1)) ** (($dat
a['n'] + 1) / ($data['n'] - 1)));

$data['w'] = ($data['o'] / 1) * $data['s'] * $data['p'] * SQRT(($data['n']
* $data['a'] * 32) / (1545 * $data['h']) * (2 / ($data['n'] + 1)) ** (($dat
a['n'] + 1) / ($data['n'] - 1)));

$data['x'] = ($data['o'] / 1) * $data['t'] * $data['p'] * SQRT(($data['n']
* $data['a'] * 32) / (1545 * $data['h']) * (2 / ($data['n'] + 1)) ** (($dat
a['n'] + 1) / ($data['n'] - 1)));


$data['z'] = 180 * MIN($data['u'], $data['x']);

$data['va'] = 180 * MIN($data['v'], $data['x']);

$data['vb'] = 180 * MIN($data['w'], $data['x']);

$data['vc'] = 180 * MIN($data['x'], $data['x']);


$data['ve'] = MIN(($data['vd'] + $data['z']), $data['y']);

$data['vf'] = MIN(($data['vd'] + $data['va']), $data['y']);

$data['vg'] = MIN(($data['vd'] + $data['vb']), $data['y']);

$data['vh'] = MIN(($data['vd'] + $data['vc']), $data['y']);

if ($data['ve'] > 10000) $data['release_type_mass_avail1'] = "INSTANTANEOUS
";

else $data['release_type_mass_avail1'] = "CONTINUOUS";

if ($data['vf'] > 10000) $data['release_type_mass_avail2'] = "INSTANTANEOUS
";

else $data['release_type_mass_avail2'] = "CONTINUOUS";

if ($data['vg'] > 10000) $data['release_type_mass_avail3'] = "INSTANTANEOUS
";

else $data['release_type_mass_avail3'] = "CONTINUOUS";

if ($data['vh'] > 10000) $data['release_type_mass_avail4'] = "INSTANTANEOUS
";

else $data['release_type_mass_avail4'] = "CONTINUOUS";


$data['detection'] = "C";

$data['isolation'] = "B";
```

```
$data['max_leak_duration_small'] = 60;
$data['max_leak_duration_medium'] = 40;
$data['max_leak_duration_large'] = 20;
$data['max_leak_duration_rupture_vt'] = 1;
$data['vt'] = $data['max_leak_duration_rupture_vt'];


$data['vj'] = $data['u'] * (1 - $data['vi']);
$data['vk'] = $data['v'] * (1 - $data['vi']);
$data['vl'] = $data['w'] * (1 - $data['vi']);
$data['vm'] = $data['x'] * (1 - $data['vi']);


$data['leak_duration_small'] = 60;
$data['leak_duration_medium'] = 40;
$data['leak_duration_large'] = 20;
if (MIN(($data['vh'] / $data['x']), (60 * $data['vt'])) > $data['vt']) $dat
a['leak_duration_rupture_vn'] = $data['vt'];
else $data['leak_duration_rupture_vn'] = MIN(($data['vh'] / $data['x'] * 60
 * $data['vt']));
$data['vn'] = $data['leak_duration_rupture_vn'];


$data['release_mass_small'] = MIN(($data['u'] * ($data['leak_duration_small
'] * 60)), $data['ve']);
$data['release_mass_medium'] = MIN(($data['v'] * ($data['leak_duration_medi
um'] * 60)), $data['vf']);
$data['release_mass_large'] = MIN(($data['w'] * ($data['leak_duration_large
'] * 60)), $data['vg']);
$data['release_mass_rupture_vo'] = MIN(($data['x'] * ($data['vn'] * 60)), $
data['vh']);
$data['vo'] = $data['release_mass_rupture_vo'];


$data['vp'] = 43 * ($data['vj'] ** 0.98);
$data['vq'] = 43 * ($data['vk'] ** 0.98);
$data['vr'] = 43 * ($data['vl'] ** 0.98);
$data['vs'] = 41 * ($data['vo'] ** 0.67);


$data['vu'] = 280 * ($data['vj'] ** 0.95);
$data['vv'] = 280 * ($data['vk'] ** 0.95);
$data['vw'] = 280 * ($data['vl'] ** 0.95);
```

```
$data['vx'] = 1079 * ($data['vo'] ** 0.62);

$data['vy'] = 110 * ($data['vj'] ** 0.96);
$data['vz'] = 110 * ($data['vk'] ** 0.96);
$data['vva'] = 110 * ($data['vl'] ** 0.96);
$data['vvb'] = 79 * ($data['vo'] ** 0.67);

$data['vvc'] = 745 * ($data['vj'] ** 0.92);
$data['vvd'] = 745 * ($data['vk'] ** 0.92);
$data['vve'] = 745 * ($data['vl'] ** 0.92);
$data['vvf'] = 3100 * ($data['vo'] ** 0.63);

$data['vvh'] = $data['vp'] * (1 - $data['vvg']);
$data['vvi'] = $data['vq'] * (1 - $data['vvg']);
$data['vvj'] = $data['vr'] * ((1 - $data['vvg']) / (4*LOG10(2.205* $data['r
elease_mass_large']) - 15));
$data['vvk'] = $data['vs'] * ((1 - $data['vvg']) / (4 * LOG10(2.205 * $data
['vo']) - 15));

$data['vvl'] = $data['vu'] * (1 - $data['vvg']);
$data['vvm'] = $data['vv'] * (1 - $data['vvg']);
$data['vvn'] = $data['vw'] * ((1 - $data['vvg']) / (4 * LOG10(2.205* $data[
'release_mass_large']) - 15));
$data['vvo'] = $data['vx'] * ((1 - $data['vvg']) / (4 * LOG10(2.205 * $data
['vo']) - 15));

$data['vvp'] = $data['vy'] * (1 - $data['vvg']);
$data['vvq'] = $data['vz'] * (1 - $data['vvg']);
$data['vvr'] = $data['vva'] * ((1 - $data['vvg']) / (4 * LOG10(2.205*$data[
'release_mass_large']) - 15));
$data['vvs'] = $data['vvb'] * ((1 - $data['vvg']) / (4 * LOG10(2.205 * $dat
a['vo']) - 15));

$data['vvt'] = $data['vvc'] * (1 - $data['vvg']);
$data['vvu'] = $data['vvd'] * (1 - $data['vvg']);
$data['vvv'] = $data['vve'] * ((1 - $data['vvg']) / (4 * LOG10(2.205* $data
['release_mass_large']) - 15));
$data['vvw'] = $data['vvf'] * ((1 - $data['vvg']) / (4 * LOG10(2.205 * $dat
a['vo']) - 15));
```

```
$data['vvx'] = MIN(($data['vj'] / 55.6), 1);
$data['vvy'] = MIN(($data['vk'] / 55.6), 1);
$data['vvz'] = MIN(($data['vl'] / 55.6), 1);
$data['vvva'] = MIN(($data['vm'] / 55.6), 1);

$data['vvvb'] = 0 * $data['vvx'] + ($data['vvh'] * (1 - $data['vvx']));
$data['vvvc'] = 0 * $data['vvy'] + ($data['vvi'] * (1 - $data['vvy']));
$data['vvvd'] = $data['vvj'] * $data['vvz'] + (0 * (1 - $data['vvz']));
$data['vvve'] = $data['vvk'] * $data['vvva'] + (0 * (1 - $data['vvva']));

$data['vvvf'] = 0 * $data['vvx'] + ($data['vvl'] * (1 - $data['vvx']));
$data['vvvg'] = 0 * $data['vvy'] + ($data['vvm'] * (1 - $data['vvy']));
$data['vvvh'] = $data['vvn'] * $data['vvz'] + (0 * (1 - $data['vvz']));
$data['vvvi'] = $data['vvo'] * $data['vvva'] + (0 * (1 - $data['vvva']));

$data['vvvj'] = 0 * $data['vvx'] + ($data['vvp'] * (1 - $data['vvx']));
$data['vvvk'] = 0 * $data['vvy'] + ($data['vvq'] * (1 - $data['vvy']));
$data['vvvl'] = $data['vvr'] * $data['vvz'] + (0 * (1 - $data['vvz']));
$data['vvvm'] = $data['vvs'] * $data['vvva'] + (0 * (1 - $data['vvva']));

$data['vvvn'] = 0 * $data['vvx'] + ($data['vvt'] * (1 - $data['vvx']));
$data['vvvo'] = 0 * $data['vvy'] + ($data['vvu'] * (1 - $data['vvy']));
$data['vvvp'] = $data['vvv'] * $data['vvz'] + (0 * (1 - $data['vvz']));
$data['vvvq'] = $data['vvw'] * $data['vvva'] + (0 * (1 - $data['vvva']));

$data['vvvt'] = ($data['vvvf'] * $data['vvvs']) + ($data['vvvb'] * (1 - $da
ta['vvvs']));
$data['vvvu'] = ($data['vvvg'] * $data['vvvs']) + ($data['vvvc'] * (1 - $da
ta['vvvs']));
$data['vvvv'] = ($data['vvvh'] * $data['vvvs']) + ($data['vvvd'] * (1 - $da
ta['vvvs']));
$data['vvvw'] = ($data['vvvi'] * $data['vvvs']) + ($data['vvve'] * (1 - $da
ta['vvvs']));


$data['vvvx'] = ($data['vvvn'] * $data['vvvs']) + ($data['vvvj'] * (1 - $da
ta['vvvs']));
```

```
$data['vvvy'] = ($data['vvvo'] * $data['vvvs']) + ($data['vvvk'] * (1 - $data['vvvs']));

$data['vvvz'] = ($data['vvvp'] * $data['vvvs']) + ($data['vvvl'] * (1 - $data['vvvs']));

$data['vvvva'] = ($data['vvvq'] * $data['vvvs']) + ($data['vvvm'] * (1 - $data['vvvs']));


$data['vvvvb'] = 0.000008;

$data['vvvvc'] = 0.00002;

$data['vvvvd'] = 0.000002;

$data['vvvve'] = 0.0000006;

$data['vvvvf'] = 0.0000306;



$data['vvvvg'] = (($data['vvvvb'] * $data['vvvt']) + ($data['vvvvc'] * $data['vvvu']) + ($data['vvvvd'] * $data['vvvv']) + ($data['vvvve'] * $data['vvvw'])) / $data['vvvvf'];

$data['vvvvh'] = (($data['vvvvb'] * $data['vvvx']) + ($data['vvvvc'] * $data['vvvy']) + ($data['vvvvd'] * $data['vvvz']) + ($data['vvvve'] * $data['vvvva'])) / $data['vvvvf'];

$data['cof_score'] = MAX($data['vvvvg'], $data['vvvvh']);


$cat;

switch (true) {

  case ($data['cof_score'] <= 100):

    $cat = "A - Insignificant";

    break;

  case ($data['cof_score'] > 100 && $data['cof_score'] <= 1000):

    $cat = 'B - Minor';

    break;

  case ($data['cof_score'] > 1000 && $data['cof_score'] <= 10000):

    $cat = 'C - Moderate';

    break;

  case ($data['cof_score'] > 10000 && $data['cof_score'] <= 100000):

    $cat = 'D - Major';

    break;

  case ($data['cof_score'] > 100000):

    $cat = 'E - Severe';
```

```
    break;
}

$data['cof_category'] = $cat;
```

```
<?php

echo "<style>
span[id^='edit'] {
  color: red !important;
}
</style>";

include_once(__DIR__ . "/../include/dbcommon.php");
include_once("df_thinning_fn.php");
include_once("df_external_corrosion_fn.php");
include_once("cof_fn.php");

$dfThinning = dfThinning($data['id']);
$dfExternalCorrosion = dfExternalCorrosion($data['id']);

$componentTypeId = DB::DBLookup("SELECT component_type FROM component_data
WHERE equipment_id = " . $data['id']);
$gff = DB::DBLookup("SELECT gff FROM component_data_type WHERE id = $compon
entTypeId");
$totalDf = $dfThinning + $dfExternalCorrosion;
$pofScore = $gff * $totalDf * 1;

if (!function_exists('getRiskDescription')) {
  function getRiskDescription($pof, $totalDF)
  {
    switch (true) {
      case ($pof < 0.0000306 && $totalDF <= 1):
        return "1 - Very Unlikely";
      case ($pof > 0.0000306 && $pof < 0.000306 && $totalDF > 1 && $totalDF
 <= 10):
```

```
        return "2 - Unlikely";
      case ($pof > 0.000306 && $pof < 0.00306 && $totalDF > 10 && $totalDF
<= 100):
        return "3 - Possible";
      case ($pof > 0.00306 && $pof < 0.0306 && $totalDF > 100 && $totalDF <
= 1000):
        return "4 - Likely";
      case ($pof > 0.0306 && $totalDF > 1000):
        return "5 - Very Likely";
      default:
        return "Unknown";
    }
  };
};


$pofCategory = getRiskDescription($pofScore, $totalDf);


$data['total_damage_factor'] = number_format($totalDf, 3);
$data['pof_score'] = sprintf('%.2E', $pofScore);
$data['pof_category'] = $pofCategory;
$data['representative_fluid'] = "C1 - C2";
$data['fluid_phase'] = 'Gas';
$data['cof_score'] = cofScore($data['id']);
$data['cof_category'] = cofCategory($data['cof_score']);
$data['risk_score'] = number_format($data['pof_score'] * $data['cof_score']
, 4);
$data['risk_score2'] = number_format($data['risk_score'] * 0.092903, 4);


$stripePofCategory = str_replace(" ", "", explode("-", $pofCategory)[0]);
$stripeCofCategory = str_replace(" ", "", explode("-", $data['cof_category'
])[0]);


switch ($stripeCofCategory) {
  case 'A':
    if ($stripePofCategory == 1 || $stripePofCategory == 2 || $stripePofCat
egory == 3) $risk = 'Low';
    else $risk = "Medium";
    break;
```

```
  case 'B':
    if ($stripePofCategory == 1 || $stripePofCategory == 2) $risk = 'Low';
    else if ($stripePofCategory == 3 || $stripePofCategory == 4) $risk = "M
edium";
    else $risk = "Medium High";
    break;
  case 'C':
    if ($stripePofCategory == 1) $risk = 'Low';
    else if ($stripePofCategory == 2 || $stripePofCategory == 3) $risk = "M
edium";
    else $risk = "Medium High";
    break;
  case 'D':
    if ($stripePofCategory == 1 || $stripePofCategory == 2) $risk = 'Medium
';
    else if ($stripePofCategory == 3 || $stripePofCategory == 4) $risk = "M
edium High";
    else $risk = "High";
    break;
  case 'E':
    if ($stripePofCategory == 1) $risk = 'Medium';
    else if ($stripePofCategory == 2 || $stripePofCategory == 3) $risk = "M
edium High";
    else $risk = "High";
    break;
  default:
    $risk = "Unknown";
    break;
};


$data['risk_level'] = $risk;


$graphTick = strtolower($stripeCofCategory . $stripePofCategory);
$data[$graphTick] = "<h2></h2>";
```

```
<?php


 class eventclass_inspection_planning  extends eventsBase
{
        function __construct()
        {
        // fill list of events
                $this->events["BeforeProcessList"]=true;


                $this->events["BeforeEdit"]=true;


                $this->events["ProcessValuesEdit"]=true;


                $this->events["BeforeProcessRowList"]=true;
        }
// List page: Before process
function BeforeProcessList($pageObject)
{
                if(isset($_GET['f'])){
        if($_GET['f'] != 'all' || $_GET['f'] != '' || $_GET['f'] != null)$_
SESSION['equipment'] = $_GET['f'];
        else if(isset($_SESSION['equipment'])){
                header("Location: inspection_planning_list.php?f=".$_SESSION
['equipment']);
                exit();
        };
}else{
        if(isset($_SESSION['equipment'])){
                header("Location: inspection_planning_list.php?f=".$_SESSION
['equipment']);
                exit();
        };
};
;
} // function BeforeProcessList
                              // Before record updated
```

```
function BeforeEdit(&$values, &$sqlValues, $where, &$oldvalues, &$keys, &$message, $inline, $pageObject)
{
		unset($values['plan_date']);
unset($values['rec_thinning_intrusive']);
unset($values['rec_thinning_non_intrusive']);
unset($values['rec_external_corrosion']);
return true;
;
} // function BeforeEdit


				// Process record values
function ProcessValuesEdit(&$values, $pageObject)
{
		include("control/df_thinning_fn.php");
include("control/df_external_corrosion_fn.php");
include("control/cof_fn.php");


$dfThinning = dfThinning($values['equipment_id']);
$dfExternalCorrosion = dfExternalCorrosion($values['equipment_id']);


$componentTypeId = DB::DBLookup("SELECT component_type FROM component_data WHERE equipment_id = " . $values['equipment_id']);
$gff = DB::DBLookup("SELECT gff FROM component_data_type WHERE id = $componentTypeId");
$totalDf = $dfThinning + $dfExternalCorrosion;
$pofScore = $gff * $totalDf * 1;
$cofScore = cofScore($values['equipment_id']);
$riskScore = $pofScore * $cofScore;
$riskScore = $riskScore * 0.092903;


if(doubleval($values['risk_target']) < doubleval($riskScore))$values['plan_date'] = date('d-m-Y', strtotime($values['rbi_date']));
else $values['plan_date'] = date('d-m-Y', strtotime($values['last_inspection'] . ' +13 years+6 months'));
;
} // function ProcessValuesEdit
// List page: Before record processed
```

```
function BeforeProcessRowList(&$data, $pageObject)
{
                $data['plan_date'] = $data['rbi_date'];
return true;
;
} // function BeforeProcessRowList
}
?>
```

AUTHOR BIOGRAPHY

The author was born in Wonosobo on May 7, 2001, and is the first of two children of Herman Antono and Sri Mulatsih. Growing up in Pekalongan, the author completed his formal high school education at SMA N 1 Pekalongan. After graduating from high school in 2019, the author joined the ITS Mandiri & Kemitraan program and was accepted at the Department of Marine Engineering FTK-IITS in 2019 and registered with NRP 04211941000049.

While studying at the Department of Marine Engineering, the author was active as an administrator of the Marine Engineering Student Association (HIMASISKAL) in the Department of Student Welfare, Himasiskal Activation 2021. After completing studies at the Hochschule Wismar, Germany, for one semester, the author joined the Indonesian Student Association Rostock in 2022. Some of the training that had participants included the Risk-Based Inspection Training program organized by AMPP ITS and PT Aneka Patra Integrity and Basic Project Management Training by Teknokrat Muda. The author was a member of the Digital Marine Operation and Maintenance (DMOM) Laboratory and had become a speaker at an Asset Integrity Management (AIM) seminar.

In addition, the author has also had the opportunity to take part in practical work at PT Dok Kodja Bahari North Jakarta and PT Pertamina Gas (Operation East Java Area) Surabaya.

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