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RISK ASSESSMENT ANALYSIS OF PRESURE VESSEL REFRIGERANT ACCUMULATOR AT PT XYZ

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Abstract
The Refrigerant Accumulator equipment is a pressure vessel located within the production system unit, namely the Dew Point Control (DPC) Unit. The Refrigerant Accumulator is a crucial component within the DPC Unit as it serves as a reservoir for the Propane refrigerant liquid. In case of a failure of this equipment, it would halt the entire process in the DPC Unit and impact the control of gas dew point that is transmitted to consumers through pipelines. Hence, a more effective method is required to prevent failures in the Refrigerant Accumulator. One of the methods that can assist in more effective inspection is Risk-Based Inspection (RBI). Risk-Based Inspection is a risk-based inspection methodology, where the main output obtained is an inspection plan determined based on the risk of the equipment. It prioritizes inspections for equipment with higher risk of damage, thus optimizing equipment maintenance and aiding companies in establishing effective maintenance strategies. Therefore, this study aims to analyze the risk level of the Refrigerant Accumulator equipment using the Risk-Based Inspection method according to API 581, determine the risk level of the Refrigerant Accumulator equipment, and provide appropriate inspection planning recommendations for the Refrigerant Accumulator equipment. Based on the results of this study, the Risk-Based Inspection analysis yielded values for Probability of Failure (PoF), Area-based Consequence (CA), and Financial Consequence (FC) through quantitative calculations based on the steps outlined in API 581. The PoF value is 5.011×10-6, the CA value is 3,316.36 ft2, and the FC value is $22,746,756.91. From the analysis results, the risk level of the Refrigerant Accumulator equipment is categorized as Medium-Risk, with a Probability of Failure of 5.011×10-6 in category 1 and a Consequence of Failure of $22,746,756.91 in category E. Consequently, the final category is 1E, with a remaining life of 33.7 years. Based on the obtained risk level, the recommended inspection planning is to conduct the next inspection on December 2031, using Visual Inspection method with 100% surface coverage and Phased Array Ultrasonic Testing (PAUT) with 90% surface coverage.

Keywords:
Refrigerant accumulator; presure vessel; risk based inspection; probability of failure; consequence of failure

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1. Introduction

The oil and gas industry are one of the largest economic sectors in Indonesia [1]. The use of oil and natural gas is crucial for industrial, transportation, and household purposes. The oil and gas industry comprises several stages, including exploration, production, and distribution. Oil and gas companies employ highly complex and diverse equipment such as pressure vessels, relief devices, piping, boilers, heaters, and other production facilities [2,3].

PT. XYZ is a company involved in the oil and gas industry, including exploration, exploitation, and the sale of oil and gas production. PT. XYZ operates numerous central processing plants (CPPs) for gas production, one of which is CPP Matindok located in Central Sulawesi. In the production of gas for delivery to consumers, various equipment and production system units are involved, including the Dew Point Control Unit (DPCU). The DPCU's role is to prevent gas from condensing during transportation through pipelines to consumers [4]. One of the equipment components within the DPCU is the pressure vessel refrigerant accumulator. This pressure vessel serves as a container for refrigerant from the thermosyphon tank, which is then directed to the refrigerant compressor suction drum to cool the gas in the oil separator.

The construction of the pressure vessel refrigerant accumulator began in 2015 and has been in up to date. The refrigerant accumulator is a crucial component in the DPCU, as it serves as a reservoir for refrigerant, which significantly affects the gas dew point control process. Over time, the pressure vessel can experience performance degradation or damage, primarily due to intensive use and environmental conditions. Any failure in the pressure vessel can disrupt or even halt the gas cooling process, potentially leading to accidents or serious incidents, including leaks, fires, and explosions that can endanger personnel, the environment, and company assets. Therefore, it is essential to ensure that the Refrigerant Accumulator is in good and safe working condition. One way to ensure equipment condition is through periodic inspections (time-based) [5]. Periodic inspections are scheduled at fixed intervals, regardless of the actual equipment condition or risk. However, conducting periodic inspections on pressure vessels can consume unnecessary maintenance time, costs, and significant resources.

Based on the preceding paragraph, there is a need for a more effective method to prevent failures in the pressure vessel, not solely based on time but also on equipment risk (risk-based). One method that can help oil and gas companies conduct inspections more effectively is Risk-Based Inspection (RBI). Risk-Based Inspection is a risk-based inspection methodology, where the main output is an inspection plan determined based on the equipment's risk level [2]. Risk-Based Inspection prioritizes inspections on equipment with a higher risk of failure [6], maximizing maintenance on critical equipment and helping oil and gas companies establish sound maintenance strategies.

In this research, a quantitative approach is employed, following the API Recommended Practice 581 2016 Addendum II 2020. API 581 is chosen as the standard code because it is closely related to Risk-Based Inspection and provides detailed quantitative methodology for risk assessment and determining appropriate inspection and maintenance strategies. A quantitative approach is used in this study due to its higher precision compared to qualitative methods. By applying a quantitative approach, detailed calculations can be obtained, and we can determine the appropriate inspection planning and mitigation methods for the pressure vessel refrigerant accumulator.

Based on the background outlined. The main objectives of this study are as follows: (1) conducting a risk analysis of the Refrigerant Accumulator using the Risk-Based Inspection method in API 581; (2) determining the risk level of the Refrigerant Accumulator; and (3) proposing recommendations for an appropriate inspection plan for the Refrigerant Accumulator.

2. Method

This risk assessment is conducted based on Risk Based Inspection (RBI) methodology as stated in American Petroleum Institute (API) 581. API 581 [5] provides a basis for quantifying risk systematically. The philosophy stems from the source of failure, that is the loss of containment from the pressurized boundary resulting in leakage or rupture from the pressurized containment. The output of the assessment if risk ranking which serves as the basis for conducting inspection as well as performing mitigation tasks. Figure 1 shows the methodology of RBI as stated in API 581 [5].

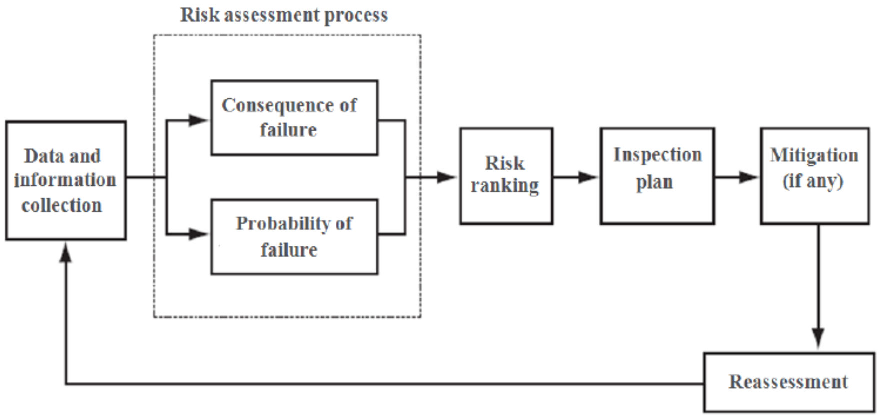

Fig. 1. Risk Assessment Methodology [5]

A. Data Collection

The problem identified in this research is the pressure vessel refrigerant equipment in the Dew Point Control Unit (DPCU), which was built in 2015. The DCPU has only been inspected once in 2021, and no assessment has been conducted on the pressure vessel equipment, therefore, the risk associated with the pressure vessel is unknown. The data required for the risk assessment analysis consists of P&ID and PFD, equipment design data, inspection and equipment history data, process operation data, factor management system data, cost factors (replacement or repair costs, waste mitigation costs, injury costs), and population density.

B. Risk Assessment

The process of performing risk assessment analysis is shown in Figure 1. The risk assessment analysis includes the calculation of Probability of Failure (PoF) and Consequence of Failure (CoF). The relationship between risk, POF and COF is shown in equation (1). The output of the risk assessment is risk ranking. From the risk ranking, inspection plan and mitigation plan can be made accordingly. This cycle is repeated by updating the information from the inspection and mitigation activity.

$$\text{Risk} = \text{Probability of Failure} \times \text{Consequence of Failure} \quad (1)$$

C. Probability of Failure

The Probability of Failure (Pf(t)) is obtained by deriving the generic failure frequency (gff), management system factor (FMS) and damage factor (Df(t)).

$$Pf(t) = gff \cdot Df(t) \cdot FMS \quad (2)$$

Generic failure frequency is a probability of failure developed for specific component type based on a large population of component data that does not include the effect of specific damage mechanism [2]. Management system factor indicates the evaluation of facility's management system, which may consists of plant management, operations, inspection, maintenance, engineering, training and safety personnel. The management system factor may be obtained through a series of interviews. The higher the facility scores indicate the low value of FMS, which eventually contributes to low probability of failure. Damage factor describes the mechanism by which the damage occurs. There are several types of damage mechanism, such as thinning, stress corrosion cracking, high hydrogen attack, mechanical fatigue, etc. API 571 [7] provides identification for several damage factors.

D. Consequence of Failure (CoF)

The consequence of failure (CoF) is analyzed from two categories, namely the consequence area (CA) and the consequence of financial (CF). The consequence area is determined from the impact when a certain amount of working fluid under observation is to be released. The release type, whether instaneous or continuous also play important roles in determining the amount of fluid released. The impact is observed from the damage area resulted if the working fluid is flammable; and also from the number of population affected if the working fluid contains toxicity. On the other hand, consequence financial is accounted by the cost for replacement or repair component, cost of loss of production, cost of accidents, cost of damage to equipment or component around it and cost of environmental pollution.

E. Case Study

The equipment investigated in this study is a pressure vessel refrigerant accumulator located in DPC Unit, CPP Matindok. The refrigerant accumulator has undergone inspection only once, which was the measurement of wall thickness on December 7, 2021, using the Non-destructive Testing (NDT) method, specifically Ultrasonic Testing. The measurement was performed on several components of the pressure vessel, taking the minimum thickness. The damage mechanism identified to occur in DPC unit are thinning and external corrosion. The value of generic failure frequency is obtained from API 581, which is 0.0000306 failures/year for pressure vessel [5]. The Management System Factor (FMS) is obtained by performing survey. The FMS value has been determined based on the results of an audit conducted at the company and is equal to 0.43.

3. Result and Discussion

In this research, the refrigerant accumulator was divided into several components, namely: shell 1, shell 2, head front, head rear , nozzle 1, nozzle 2 and nozzle 3. The purpose of the division is to understand the risk possesses on each component constructing the refrigerant accumulator. Tabel 2 shows the summary of variabel needed to calculate the probability of failure.

Table 1. Probability of Failure (PoF)

Component	gff	Df(t)	FMS	POF	***Category***
Shell-1	0.0000306	0.3808	**0.43**	**5.01×10^{-6}**	**1**
Shell-2		0.3669		**4.82×10^{-6}**	**1**
Head-front		0.2122		**2.79×10^{-6}**	**1**
Head-rear		0.2147		**2.82×10^{-6}**	**1**
Nozzle-1		0.1466		**1.93×10^{-6}**	**1**
Nozzle-2		0.1609		**2.11×10^{-6}**	**1**
Nozzle-3		0.1667		**2.19×10^{-6}**	**1**

The highest probability of failure for components constructing the refrigerant accumulator is 5.01×10-6, by which this value is classified as category 1, according to API 581 [7].
The fluid contained in the refrigerant accumulator is flammable and is not in the form of steam, acids, or caustics. In addition to that, the fluid does not contain toxicity. The evaluation regarding the area-based flammable consequences calculation for both component damage and personnel injury can be seen in Table 2.

Table 2. Component Damage and Personnel Injury Consequence Area

Component Damage CA	1,305.91 ft2
Personnel Injury CA	3,316.36 ft2

The value of the Final Consequence Area is determined from the highest value between component damage or personnel injury. Therefore, the consequence area is taken from personnel injury consequence are, which is 3,316.36 ft2. Thus number is classified as category C according to API 581 [5]

The calculation of financial consequences is based on the recommendations from API 581, as well as the costs for equipment replacement, production loss, population density, and personnel injury costs. The financial consequence for this case is estimated to be $22,746,756.91. This number is categorized as E class, according to API 581 [5].

Based on the analysis of the Probability of Failure (PoF) and Consequence of Failure (CoF), these values are input into the risk matrix. The risk ranking for the pressure vessel refrigerant accumulator equipment in term of areas based is shown in Figure 2. From this figure, it can be observed that the risk for area based in classified as low risk.

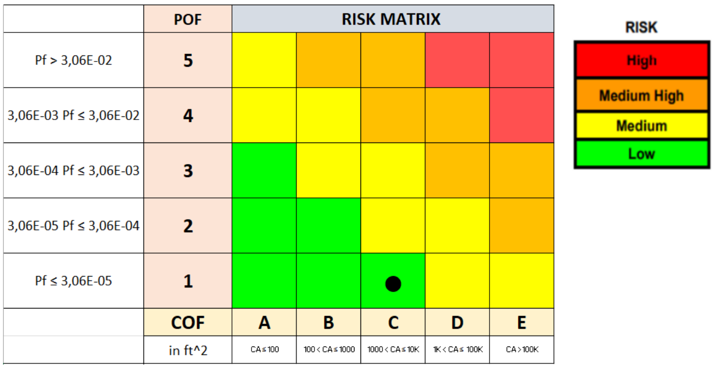

Figure 2 Area-based Risk Matrix

In addition to that, another risk matrix is constructed to determine the risk ranking in term of financial based. Figure 3 shows the risk ranking for financial based. From this figure it can be observed that the financial risk is categorized as medium risk.

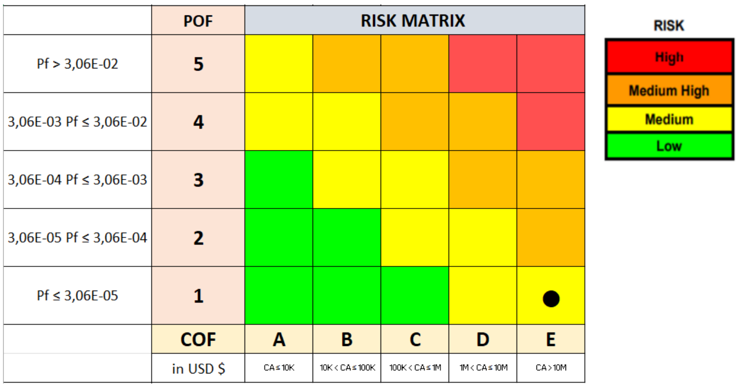

Figure 3 Financial-based Risk Matrix

From the two risk ranking shown in Fig. 2 and Fig. 3, the inspection plan and mitigation plan can be formulated by taking consideration of the highest possible risk posses by the refrigerant accumulator. Therefore, the risk level for the refrigerant accumulator equipment is category 1E (Medium-risk).
The remaining life of the refrigerant accumulator can be calculated to be 33.7 years with corrosion rate to be 0.186 mm/year. Since the remaining life of the equipment is greater than 10 years, therefore, according to API 510 [8] the next inspection date can be determined as 10 years from the previous inspection date. As stated previously that the previous inspection date was performed on December 2021, therefore, the next inspection date is expected to be performed on December 2031. The inspection plan to be performed can be formulated based on API 572 Section 9 [10], by which, the inspection method for the internal thinning damage factor is to perform Non-destructive Examination (NDE). The selected NDE method is based on the guidelines in ASME Sec. V Non mandatory Appendix E – Computerized Imaging Techniques [11], specifically the Phased Array Ultrasonic Testing (PAUT) method.

For external corrosion, according to API 572 Section 9 [10] the recommended method for the External Corrosion damage factor is visual inspection of the entire surface and components of the pressure vessel. This inspection should include checking for damaged areas, cracks, bolt tightness, the condition of paint coatings, supports, handrails, and corrosion indications.

4. Conclusion

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Based on the results of the conducted research, the conclusion of the research is:

1. Risk analysis was performed using the Risk-based Inspection method by calculating the Probability of Failure (PoF) and Area-based Consequence (CA), as well as Financial Consequence (FC), based on API 581. The probability of failure is 5.011×10-6, the consequence of failure is 3,316.36 ft2, and the financial consequence is expected to be $22,746,756.91.
2. The risk level of the Pressure Vessel Refrigerant Accumulator is in the Medium-Risk category, with a Probability of Failure of 5.011×10-6 in category 1 and a Consequence of Failure of $22,746,756.91 in category E. The remaining life of the refrigerant accumulator is expected to be 33.7 years.
3. The proposed inspection planning is to conduct the next inspection in 10 years from the last inspection, which is on December 7, 2031, using the visual inspection method with 100% surface coverage, and using the Phased Array Ultrasonic Testing (PAUT) method with 90% surface coverage.

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