Risk-Based Inspection of Crude and Refined Oil Storage Tank in Indonesia Refinery Plant

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Abstract. Oil Storage Tank whether crude or refined oil is high risk facilities which demand further attention on the safety aspect. As a preventive action, government of Indonesia had issued a regulation that obligate every Oil and Gas Company to conduct a technical inspection of storage tank with Time-Based or Risk-Based Method. Time Based Inspection often results in ineffective inspections method or excessive inspections interval, while Risk-Based Inspection is more effective and efficient. This study aims to determine inspection plan of Crude and Refined Oil Storage Tank in Indonesia Refinery Plant using Risk Based Inspection method. There are 3 damage mechanisms defined in shell of Storage Tank: Atmospheric Corrosion, General Corrosion, and Corrosion under Insulation. Risk analysis calculation using defined damage and technical data collected, shows all Storage Tank which being studied belong to medium risk category. Inspection method suggested were visual inspection and UT thickness/scanning, while inspection interval can be extended to 10 years. Based on this study, implementation of RBI will benefit refinery plant with more effective and efficient inspection method.

Keywords: Damage Mechanism, Inspection Planned, Risk Analysis, Storage Tank

1. Introduction

Recently in 2021, 20 accidents recorded in the Indonesian oil and gas industry, 3 of the incidents was oil storage tanks fire at the oil and gas refinery. The fire incident in the storage tank was included in the category of major accident. In March, 4 units of fuel oil (BBM) tanks caught fire and stopped refinery operation. In June, 2 units of Petrochemical tanks caught fire and on November 1 unit of BBM tanks caught fire. In summary, there were a total of 7 oil & gas refinery storage tanks burned in 2021 [1]. Oil and gas storage tank fires in Indonesia did not just happen in 2021, it has happened several times, such as on April 2011 which resulted in 3 units of the tanks and product contained being burned, then in 2009 there was a fire in the storage tank at the fuel oil depot which contain premium type of fuel products [2]. This shows that storage tanks at oil and gas refineries in Indonesia need further attention, especially on the safety aspect.

Due to the importance of the oil storage tank safety, the government regulated it as a step to prevent an accident in the storage tank by conducting a technical inspection to be able to determine the reliability of an equipment. This is a common aspect which also regulated in various countries with its own regulation, China implemented SY/T 5921 which regulated Technical Standards on Storage Tanks and Oil and Gas transportation [3], Europe through the Integrated Pollution Prevention and Control (IPPC) policy [4], and the UK with Pressure Systems Safety Regulations 2000 No. 218[5]. Indonesia through Ministry of Energy and Mineral Resources (ESDM) has issued Minister of Energy and Mineral Resources Regulation No. 32 of 2021 concerning Technical Inspections and Safety Inspections of Equipment and Installations in Oil and Gas Business Activities [6]. As mentioned in the Regulation of the Minister of Energy and Mineral Resources No. 32 of 2021, every storage tank that stored oil or natural gas in the Oil and Gas Industry must undergo a Technical Inspection and Safety Inspection. Technical Inspections and Safety Inspections can be carried out periodically based on a certain period of time or once every 4 years (time-based inspection) or the results of risk analysis/Risk Based Inspection (RBI) [6]. Referred to this regulation, the government has opened up opportunities for companies to have inspections planning that do not require to be based on a certain time or every 4 years, instead on the risk analysis of each equipment or Risk Based Inspection (RBI).

Periodic inspection method often results in inaccurate inspections from the side of the inspection method or excessive inspections from the interval side. This is because periodic inspections do not see how the damage mechanism and risks in individual tanks, which may be different due to the service operations and tank properties. By using RBI, this issue will be considered, hence the right inspection method and interval can be obtained [7], [8]. In addition, if tanks which have higher risk are not inspected and repaired in time, there will be a potential for accidents or leaks, corrective action will lead to disruption on the production operation which cause huge loss in time and financial aspect [9].

Until this study published, no companies in Indonesia had conducted an inspection using RBI on the fuel tank according to the Minister of Energy and Mineral Resources Regulation No. 32 of 2021, even though previous studies showed that RBI was effectively used in pressure vessels [7] and Crude Oil Storage Tanks, especially those with large volumes [8], [9]. This research intended to conduct a safety study on fuel and crude oil tanks operated in Indonesian oil and gas refineries using the RBI method to obtain the right inspection method and interval.

2. Methodology

The RBI method in this study refers to the American Petroleum Institute Recommended Practice (API RP) 581 3rd Edition 2016 about Risk Based Inspection Methodology. The steps taken are broadly adopted the document methodology, starting from collecting technical data for storage tanks, determining the damage mechanism for each tank, conducting risk analysis starting from calculating the Probability of Failure (PoF), Consequences of Failure (CoF), and risk calculations, as well as making an Inspection Plan [10].

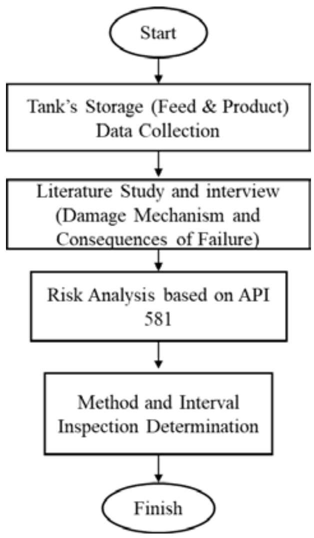

Figure 1 Flowchart of methods

Flowchart of this study can be viewed in Figure 1. Data storage tanks collected from one of the oil and gas refineries in Indonesia. Tank grouped based on the type of fluid, refinery products (in the form of BBM, naphtha, residues, and petrochemicals) and refinery feeds (in the form of crude oil). The storage tank type reviewed in this study was above ground tank, which been built based on API 650 standards. The purpose of grouping was to make it easier to find common damage mechanisms, since according to the API RP 581 method, one factor to determine damage mechanism is the type of fluid.

The next step was document review, literature study, and interview with oil and gas refinery employees to find out the damage mechanism and records of previous inspections on storage tanks. In addition, a discussion was held to determine the value of Management Systems Factor (Fms) for all tanks for which risk analysis and consequences for tank failure will be carried out. These things are needed for the calculation of CoF and PoF in conducting Risk Analysis.

CoF and PoF calculations are carried out after all the required data has been collected. The CoF used is level 1, which is a consequence based on the affected area due to loss containment. After the CoF and PoF values are obtained, the Risk Value can be calculated where this value is used to determine the level of risk. The level of risk used in this study is a 5x5 matrix with the categories of Low Risk, Medium Risk, Medium High Risk and High Risk.

Table 1 Example of result inspection method and interval

Inspection and Method				
Damage Mechanisms	**Inspection methods**	**Coverage**	**Area**	**Interval**
Atmospheric Corrosion	Visual Inspection	Visual inspection of >95% of the exposed surface area with follow-up by UT. RT or pit gauge as required	Roof, Annular	Next 4 years
General Corrosion	UT Thickness or Scanning	For the total surface area: >100% spot UT OR >10% UT scanning, automated or manual OR >10% profile radiography of the selected area(s).	Roof, Shell, Annular	
Amine Cracking	UT Flaw Scanning or MPI	Examine >35% for selected welds / weld area (Nozzles-to-shell. shell-to-shell. T-joints)	Weld Joint	

Level of risk from the results of the Risk Analysis then becomes the risk inherent in each tank. After that, the risk target is determined as the basis for determining the appropriate inspection method and interval for each storage tank containing both refinery products and refinery feed. The Inspection method contains the checks to be carried out, the coverage and the parts to be inspected, and inspection interval or next Inspection time [11]. Example of the result showed on Table 1.

3. Storage Tank

Referring to the API 650 standard, it is stated that the storage tank which includes in the scope is a tank (cylindrical) stand upright above the ground as shown in the Figure 2. The structural parts of storage tank are Bottom, Shell and Roof. In addition to these parts, there are also accessories, namely nozzles, stairway, measuring holes and manways/manholes. In this study, risk analysis performed will focused on the shell, where the shell plays an important role in maintaining the tank structure and the barrier between the oil inside and the atmosphere. As for the roof and bottom, it is only ensured that the thickness still meets API Standard 653, where the thickness of the roof is 2.29mm and the bottom is 2.54mm [12], [13].

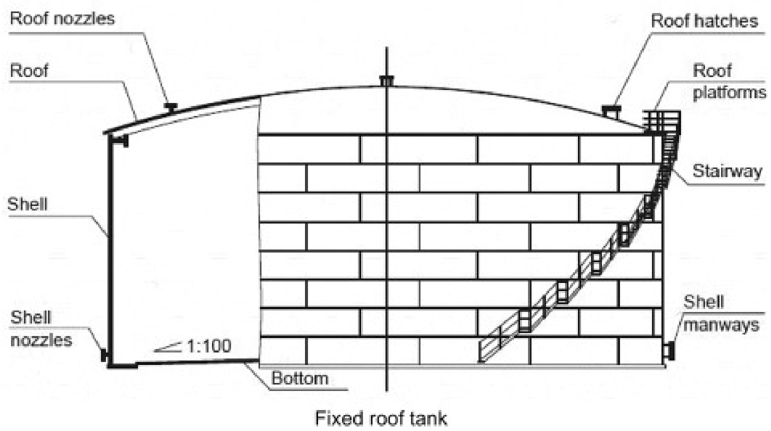

Figure 2 Standard API 650 Oil Storage Tank [15]

The selection of tank categories is based on the type of fluid and the operating process of the refinery, where the product tank contains the fluid final product from the refinery process (BBM and Petrochemical) and the feed tank where fluid still in the form of crude oil that has not been processed. As shown in table 2, for petrochemical products, only polygasoline existed, while fuel varies in type of gas oil, gasoline, kerosene, ADO, diesel fuel, oil fuel and DCO. Refinery feed products are generally crude oil with the type of Duri and Minas and Hot Condensate. In addition to the type of fluid, it is also important to know the size of the tank based on its capacity, because the larger the size of the tank, the greater the rate of heat or the risk of burning [14].

Table 2 Data of storage tank of refinery process and feed

No	**Tank Category**	**Service Fluid**	**Capacity (m^3)**	**No**	**Tank Category**	**Service Fluid**	**Capacity (m^3)**
1	Product	Polygasoline	4500	22	Feed	Crude Oil (Duri)	67000
2	Product	Polygasoline	4500	23	Feed	Crude Oil (Duri)	67000
3	Product	Gas Oil	21000	24	Feed	Crude Oil (Duri)	67000
4	Product	Gasoline	29000	25	Feed	Crude Oil (Duri)	67000
5	Product	Gasoline	29000	26	Feed	Crude Oil (Duri)	67000
6	Product	Gasoline	29000	27	Feed	Crude Oil (Duri)	67000
7	Product	Gasoline	29000	28	Feed	Crude Oil (Minas)	33500
8	Product	Kerosene	8500	29	Feed	Hot Condensate	100
9	Product	Kerosene	8500				
10	Product	ADO	19500				
11	Product	ADO	19500				
12	Product	Diesel Fuel	22000				
13	Product	Diesel Fuel	22000				
14	Product	DCO/Fuel Oil	26000				
15	Product	DCO/Fuel Oil	26000				
16	Product	Diesel Oil	2500				
17	Product	Fuel Oil	100				
18	Product	Fuel Oil	100				
19	Product	Fuel Oil	3000				
20	Product	Fuel Oil	3000				
21	Product	Diesel Fuel	22000				

29 storage tank data were obtained during data collection from one of the oil and gas refineries operating in Indonesia with the following details: 21 units storage tanks with refinery product fluids which consist of 2 units polygasoline tank, 1 unit gas oil tank, 4 units gasoline , 2 units kerosene, 2 units containing ADO, 4 units containing diesel fuel, and 6 units containing DCO/fuel oil; 9 units storage tanks containing refinery feed fluid which consist of 7 units crude oil tank and 1 unit hot condensate tank.

Apart from the type of fluid and tank capacity, the parameters of the collected tank data are material specifications, year of construction, current shell thickness, corrosion rate, insulation, and other parameters required for the calculation of CoF and PoF. Structural conditions of Plumbness, Settlement and Roundness have been confirmed in accordance with API 653, hence RBI performed could focus on the condition of the tank roof and shell material.

4. Risk Analysis

Risk Analysis is an activity to identify and analyze the potential causes and possible consequences of risk quantitatively, semi-quantitatively and qualitatively. Risk itself defined as combination of the probability of an event over a certain period of time with the consequences of that event as shown on equation (1),

$$Risk_{Failure} = Pof \ x \ Cof \ \text{........................(1)}$$

where Pof is probability of failure and Cof is consequences of failure. Probability of Failure obtained from the calculation of equation (2).

$$Pof = G_{ff} \ x \ FMS \ xD_f \ \text{.............................(2)}$$

Generic Failure Frequency or G_{ff} is the probability of failure developed by the API for certain types of components based on a large data population from the oil and gas refinery and petrochemical industries, G_{ff} components do not include the effects of certain damage mechanisms. FMS or factor management system is a multiplier of G_{ff} based on process safety management systems. These factors come from the results of the evaluation of a facility or operating unit management system that affects the risk in the refinery process. D_f or Damage Factor is an adjustment factor applied to GFF by taking into account the damage mechanism and damage conditions that exist in each equipment.

Consequences of failure or Cof are consequences if the tank fails, in this case loss containment. Cof can be calculated both based on area (level 1) and based on financial risk (level 2). Area-based consequences are calculated based on fluid type and phase and equipment operating conditions. Then the financial consequences are calculated directly by multiplying the affected area by the cost per unit area and then adding it to the business disruption costs and environmental clean-up costs. In this study, the Cof used is level 1 or area-based.

Table 3 Pof & Cof category

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

Pof categories are divided into 1-5 where the lowest is category 1, with a Pof value of less than 3.06E-05 and a D_f of less than 1. Consequence Category also divided into A - E, where category A is the smallest with a Cof value of less than 9.29 m3 Table 3[10].

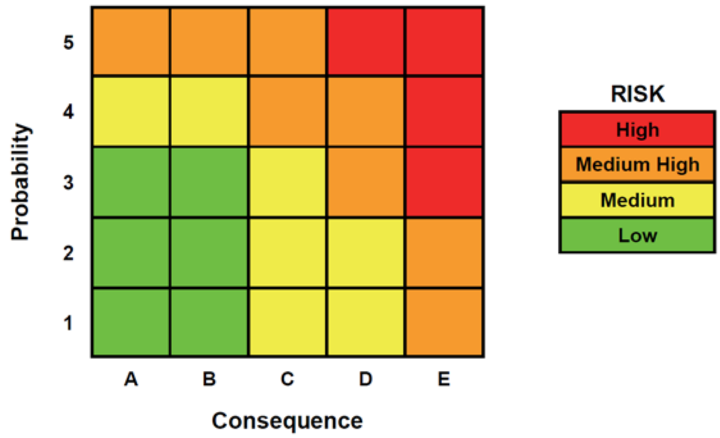

Figure 3 5x5 Risk Matrix

Basically, risk analysis will quantify all variables, both semi-quantitative and qualitative in the form of categories. The category is made based on the agreement of the parties involved. However, API RP 581 provides an example of a 5x5 risk matrix between probability and consequence as shown on Figure 3. This risk matrix will be used as a risk analysis tool for this research.

5. Damage Mechanism

Risk analysis is strongly influenced by the damage mechanism that occurs in the tank, in particular it will affect the value of the Damage Factor (D_f). As explained earlier, the D_f value will affect the PoF value where the higher the D_f, the higher the PoF value and the risk acquired. Hence understanding and determining the damage mechanism in the tank is very important.

The stages of determining the damage mechanism are starting with screening criteria by creating a table which contained tank parameters in the form of fluid type, operating pressure, and temperature. Then from the table, possible types and models of damage mechanisms that exist in the tank will be selected with brief explanation of the reason why typical damage mechanism was selected. The list of damage mechanisms that exist in equipment at the refinery can be referred to the API 571 document, which included a list of potential damage and the conditions that will trigger. There are 4 categories, namely, Mechanical and Metallurgical Failure Mechanism, Uniform or Localized Loss of Thickness, High Temperature Corrosion and Environment-Assissted Cracking[16].

It is important to determine damage mechanism categories to be matched the tank actual conditions, for example, since all storage tanks in this study have an operating temperature of less than 204°C, the High Temperature Corrosion category can be ignored. The damage mechanisms that exist in the Product and Feed refinery tanks are generally Uniform or Localized Loss of Thickness and Mechanical and Metallurgical Failure Mechanisms [17]. Focus of this research is the tank shell, thus damage mechanism can be narrowed down to the Uniform or Localized Loss of Thickness category [18].

Based on the results of determining the damage mechanism, it is known that the shells in the majority of the tanks have the following damage mechanisms: Atmospheric Corrosion, General Corrosion, and Corrosion under Insulation (for case which tank shells have insulation). Since all damage mechanisms are corrosion, the damage mode is metal loss [17]. 28 unit of 29-unit tank have damage mechanism of Atmospheric and General Corrosion, while Corrosion under Insulation damage mechanism existed in 13-unit of 29-unit which been inspected as shown on Figure 4.

Table 4 PoF, CoF value and Risk of 29 tank

No	Tank Category	Service Fluid	Tank Shell		
			Probability of Failure	Consequence of Failure	Risk Value
1	Product	Polygasoline	0,000620649	662,6201	0,4112546
2		Polygasoline	0,000620649	662,6201	0,4112546
3		Gas Oil	0,000253777	120,137	0,0304879
4		Gasoline	0,001004229	587,3745	0,5898587
5		Gasoline	0,002255373	150,1558	0,3386574
6		Gasoline	0,002365309	157,4751	0,3724773
7		Gasoline	0,001594082	106,129	0,1691783
8		Kerosene	0,000272661	530,4006	0,1446195
9		Kerosene	0,000272661	530,4006	0,1446195
10		ADO	0,000285046	113,6359	0,0323915
11		ADO	0,001004229	587,3745	0,5898587
12		Diesel Fuel	0,002357607	105,849	0,2495503
13		Diesel Fuel	0,002357607	105,849	0,2495503
14		DCO/Fuel Oil	0,002059195	109,978	0,2264661
15		DCO/Fuel Oil	0,002059195	109,978	0,2264661
16		Diesel Oil	0,00040525	104,3228	0,0422768
17		Fuel Oil	0,000104683	209,7491	0,0219571
18		Fuel Oil	0,000104683	209,7491	0,0219571
19		Fuel Oil	0,000441324	264,8805	0,1168981
20		Fuel Oil	0,000441324	264,8805	0,1168981
21		Diesel Fuel	0,000748381	183,2956	0,137175
22	Feed	Crude Oil (Duri)	0,001500999	232,1983	0,3485294
23		Crude Oil (Duri)	0,001727852	267,2916	0,4618404
24		Crude Oil (Duri)	0,000303336	469,2473	0,1423396
25		Crude Oil (Duri)	0,000303336	469,2473	0,1423396
26		Crude Oil (Duri)	0,000303336	469,2473	0,1423396
27		Crude Oil (Duri)	0,000303336	469,2473	0,1423396
28		Crude Oil (Minas)	0,000346127	184,8597	0,0639849
29		Hot Condensate	0,001716161	98,4406	0,1689399

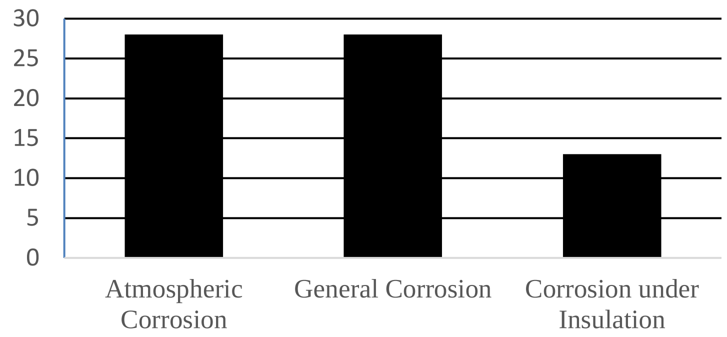

Figure 4 Damage Mechanism of Tank

6. Risk Value

Damage mechanism which had been determined will be used to calculate Damage Factor (D_f). The equation for calculating DF with the existing damage mechanism is as follows:

$$D_f = D_f^{thin} + D_f^{etd} \quad \text{.................................(3)}$$

By applying D_f to the equation (2), we will get PoF of each tank. Consequences of Failure (CoF) is defined as how big the impact is when a loss of containment occurs which is divided into component damage area and injury personnel area. Component damage area consists of 3 variables, namely, flammable consequence area, toxic consequence area and non-flammable & non-toxic area. The largest value from all these parameters, then used as the CoF value. The value of CoF in each tank can be seen in Table 4.

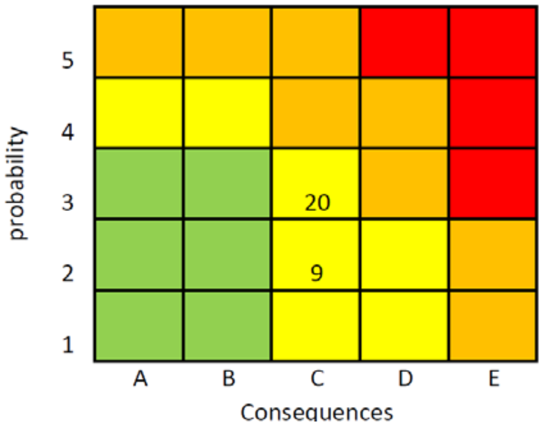

Figure 5 Tank shell risk matrix

After knowing the value of CoF and PoF, we can know the value of the risk by using equation (1). Furthermore, the CoF and PoF values are included in the risk matrix for categorization referring to Table 3, so that the risk categories for each tank can be seen. By plotting data of calculated PoF & CoF into the risk matrix, it is known that all tank which being inspected belong to medium category with details of 9 tank units in the 2C category and 20 tank units in the 3C category as shown in Figure 5.

7. Result

The inspection method adjusted to the existing damage mechanism, which refers to API RP 581. Based on the results of the risk analysis, generally the inspection method that needs to be applied is visual inspection, UT Thickness/Flaw Thickness. Additional inspection also needed with the Insulation Window on the Insulated Tank as shown in Table 5. By applying this method to shell, inspections can be carried out from the outside of tank during in-services, without the stopping the operation[19].

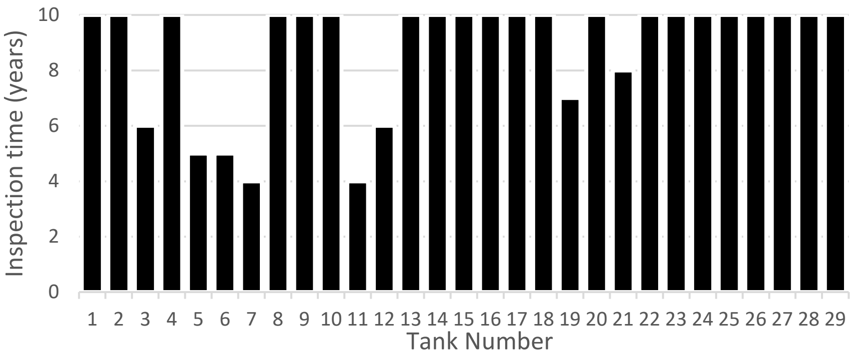

Figure 6 Interval inspection on tank

The API RP 581 inspection interval gave equipment operator the option to determine whether to do inspection when the risk target is reached or earlier. There are several methods to determine this interval, mostly referring to API 653 where the inspection interval is carried out at half the remaining service life but a maximum of 10 years. Then there are those who put the inspection interval for the remaining service life, without any maximum year interval [20]. There are also those who cannot maximize the inspection interval for the remaining service life because local regulations still require a maximum inspection interval of 5-7 years [8].

Regulations prevailed regarding inspection of Oil and Gas Storage Tanks in Indonesia, provide flexibility for operators to choose whether to use periodic inspections at 4-year intervals or RBI without any interval limit. According to the results of conducted interviews with the operators of the refinery where the data was taken, conservative option often being selected, by keep using API 653 as the maximum limits for the year interval. Thus, the inspection interval for each tank can be seen in the Figure 6.

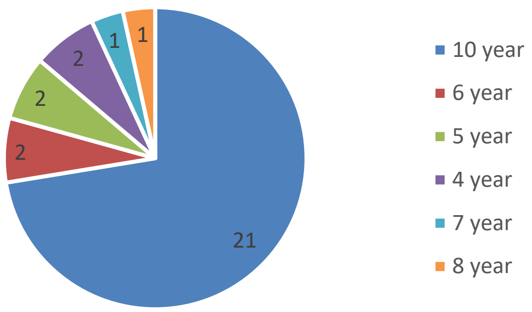

Figure 7 Number of tanks per inspection interval

Based on the Figure 7, it can be seen that with the RBI method refinery operators will get efficiency in the form of an extension of the inspection interval from 4 years to 10 years for each tank. In fact, the majority or 21 units of the tank have an inspection interval of 10 years, and more than 4 years for the rest as seen on Figure 7. There are only 2 tanks whose inspection intervals are the same as the regular inspections as stipulated in the regulation, which is 4 years. This efficiency will certainly benefit the refinery operator in terms of costs, but in trades off additional responsibility that must be taken for the option of defined inspection intervals.

Table 5 Inspection method on Tank

	Atmospheric Corrosion			General Corrosion			Corrosion under insulation		
Tank No.	Method	Cov.*	Area	Method	Cov.*	Area	Method	Cov.*	Area
1	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
2	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
3	Visual Inspection	1	Roof, Shell, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
4	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
5	Visual Inspection	1	Roof, Shell, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
6	Visual Inspection	1	Roof, Shell, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
7	Visual Inspection	1	Roof, Shell, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
8	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
9	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
10	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
11	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A

12	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
13	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
14	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
15	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
16	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
17	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
18	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
19	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
20	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
21	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	N/A	N/A	N/A
22	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
23	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
24	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
25	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
26	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
27	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
28	Visual Inspection	1	Roof, Annular	UT thickness or scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Shell
29	N/A	N/A	N/A	UT Spot / Scanning	2	Roof, Shell, Annular	Visual Inspection and UTSpot/Scanning	4	Roof, Shell, Annular

8. Discussion

The RBI in this study focuses on the shell and roof, because the consequences used are area-based, not financial. However, prior to risk analysis, an assessment has been carried out to ensure that the condition of the structure, both Plumbness, Settlement and Roundness, are in accordance with API 653. Parts other than the shell, which are the roof and bottom, in fact should be taken into account in the selection of inspection intervals. Since these 2 parts are not included in the risk analysis, refer to API 653, the maximum inspection interval should be half of the remaining service life and a maximum of 10 years.

The consideration of not maximizing the inspection interval as the risk target set out in API RP 581 is due to the precautionary principle, and it still takes 1 time to collect data for the results of the risk analysis to be verified in accordance with the predictions on the next inspection. If the difference between the results of the current risk analysis and the verification at the next inspection is not far, then the current analysis can be used with an update if any crucial data changes.

When compared to other countries, regulations in Indonesia provide more flexibility for refinery operators to use this RBI method. Because the Minister of Energy and Mineral Resources Regulation No. 32 of 2021, the government does not provide interval limits or risk analysis guidelines, everything is returned to the refinery operator. On the one hand, this has an impact on the lack of level of confidence in refinery operators because all the burden is delegated to refinery operators. Hence even though the refinery operators have made a risk analysis, until now they still prefer to choose 4-year periodic inspections. Implementation of guidelines or kind of approval from the government on the RBI method made by refinery operators may require to increase their level of confidence.

9. Conclusion

All storage tank at the oil and gas refineries studied are still in the accepted risk level (Medium) by noting that inspections are carried out with the recommended method and interval. Inspection methods on the tanks studied are generally the same because of the typical damage mechanism except for the tanks which have insulation. Then the inspection interval for all tanks was above 4 years with maximum limit of 10 years. Technical Inspections on Storage Tanks at Oil and Gas Refinery using the RBI method are more effective and efficient than regular time-based inspections.

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