A Study on The Implementatiom of Qualitative Risk based Inspection (RBI) Methods on Athmospheric Storage Tank – Shell Course

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Abstract. This study implements risk assessment toward atmospheric storage tank by using a systematic approach of Risk Based Inspection (RBI) method as provided by American Petroleum Institute (API) 581. API is one of the one of the widely used standard guideline in petroleum company around the world. The objective of this study is to perform risk assessment by calculating the probability of failure and consequence of failure for each damage factor in atmospheric storage tank. The damage factor identified for the asset under evaluation is internal thinning and external corrosion. The probability of failure was found to be falls in category 1, while the consequence of failure falls under category A. Therefore, the asset possesses low risk. Further analysis of remaining life shows that the remaining life of the storage tank is 25.07 years.

Keywords: Maintenance, RBI, API, Storage tank, POF, COF, Risk level, Mitigation

1 Introduction

Recently, Several accident occured in petrleum industries have been reportedly published in Indonesia [1 – 3]. The latest accident is the explosion in one of facility in state owned petroleum industry in Indonesia. This exposion is a result of failure which occured and its impact were affecting in various aspects. Not only it can possess risk to operator safety and production loss, but also to the environment. This indicates that a well thorough maintenance plan is need to prevent failure from happening, thus reducing the risk of experiencing explosion that can lead to fatality, environment damage and operational loss.

Storage tank is a storage medium which widely utilized in petroleum, petrochemical industries, etc. This equipment is commonly used as a storage medium in order to keep the flow of the production process running without having to wait for the distribution schedule. Other function of storage tank is to keep the containment from being contact with contaminants and damages. There are several types of storage tank, such as: aboveground storage tank underground storage tank, fixed roof tank, floating roof tank, etc [3].

American Petroleum Institute (API) is one of the widely used standard guideline in petroleum company around the world [4]. API provides a systematic approach in performing risk based

ICO-SEID 2022, November 23-24, Jakarta, Indonesia

DOI 10.4108/eai.23-11-2022.2341601

inspection (RBI) toward assets in petroleum industries. First of all, it attempts to identify the asset from asset registry. Next step is to identify the mechanism of damage which can leads asset to failure. In this step, scenarios of failure due to the actual damage mechanism is developed and considered. Probability of failure and consequence of failure are evaluated by considering all damage mechanism. Risk assessment is conducted to all of the failure scenarios.

RBI methodology produces mapping of potential risk possessed by assets. Asset with high risk will subjected to high priority and vice versa. Thus, optimal inspection palling for the assets can be produced. In addition, RBI proposed mitigation plan in the form of inspection plan to control the degradation of the asset [5]. This paper investigates the implementation of RBI on an atmospheric storage tank, on its shell course.

2 Research Methodology

Risk assessment in RBI is carried out by using a systematical procedure as provided by API [5]. The research framework of performing RBI is depicted in Fig. 1. Risk is defined as combination of probability of failure (POF) and consequence of failure (COF) of the asset, as depicted in equation (1). From this equation, it is undestood that POF and COF are two main component for determining the risk.

$$\text{Risk} = \text{POF x COF} \quad (1)$$

Probability of Failure (POF) is determined using equation (2). It compromises the expected failure frequency of any specific failure scenarios to happen (generic frequency factor/gff), damage factor (Df (t)) and management system factor (FMS) [6].

$$\text{Pof (t)} = \text{gff x Df (t) x FMS} \quad (2)$$

Equation (2) shows an statistical model generated based on generic data. The generic data is obtained for each asset and its damage mechanism under evaluation.

Generic failure frequency is estimated using records from various plants within an industry documented in literature references. Due to this, the values does not represent true failure frequency, and therefore need to be corrected based on the actual condition using damage factor and factory management system. Manaegement system factor measure the performance of facility management system when accidentoccured and its responds to handle the asset [7].

Damage factor is correction factor applied to account for damage mechanisms that are active in an asset, which modifies generic faailure frequency, thus makes it specified to the component under assessment. There are several damage mechanism which can be observed for an asset [6], for example thinning, stress orrosion cracking, external damage, brittle fracture, and mechanical fatigue. In this research, the scope of damage mechanism is limited to internal thinning and external corrosion. Table 1 shows POF and COF based API 581 [6]. Risk matrix can be constructed to show the risk distribution. **Figure 2** illustrates a 5 x 5 risk matrix based on API 581.

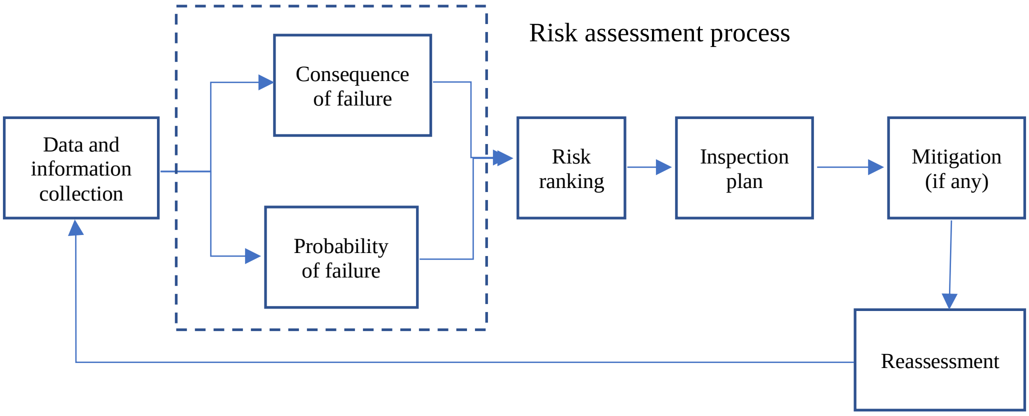

Fig. 1. RBI Planning Process [6]

Table 1. Probability and Consequence Categories in API 581 [6]

Probability Category		Consequence Category	
Category	Probability Range	Category	Range (m2)
1	$\text{POF} \leq 3.06 \times 10^{-05}$	A	$CA \leq 9.29$
2	$3.06 \times 10^{-5} < \text{POF} \leq 3.06 \times 10^{-04}$	B	$9.29 < CA \leq 92.9$
3	$3.06 \times 10^{-4} < \text{POF} \leq 3.06 \times 10^{-03}$	C	$92.9 < CA \leq 929$
4	$3.06 \times 10^{-3} < \text{POF} \leq 3.06 \times 10^{-02}$	D	$929 < CA \leq 9290$
5	$\text{POF} > 3.06 \times 10^{-05}$	E	$CA > 9290$

Risk ranking which is designated as a unit of time function with risk distribution for different components can be plotted into a risk matrix, as shown in Fig. 2. After knowing the risk level of the existing equipment, then the determination of the appropriate inspection measures and scheduling of inspection intervals are carried out and then make recommendations for mitigation plant what companies can do. Analysis is required to re-examine actions and timing inspection is appropriate and in accordance with the needs. The higher risk of an asset, the shorter the frequency of inspection; whereas the lower the risk an asset have, it longer the frequency. The remaining life the asset can be determined by using the equation (3) as follows [6]:

$$remainning\ life = \frac{t_{actual} - t_{required}}{Corrosion\ rate} \tag{3}$$

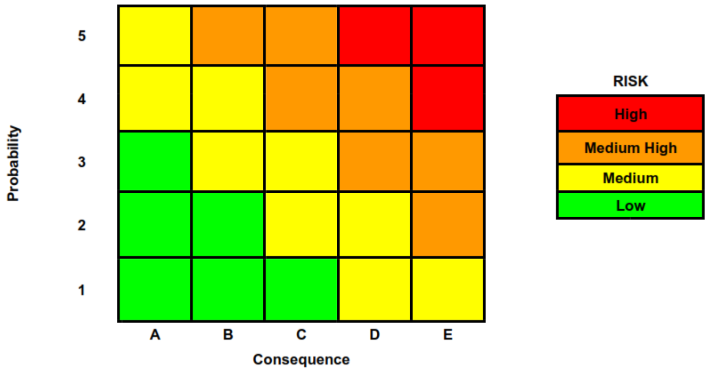

Fig. 2. Balanced Risk Matrix [6]

3 Results and Discussion

Several data were obtained from PT XYZ, a petroleum industry in Indonesia, to perform risk assessment. The asset under evaluation was atmospheric storage tank, with tag number T-201-A. The standard data on design and operational equipment under evaluation are shown in Table 2.

RBI was performed on the tank shell of storage Tank T-201-A. The Tank was divided into 4 components as shown in Table 3. Measurement data from the inspection for each component were listed in Table 4.

Calculation of POF was conducted using a statistical model which developed based on API 581. The damage mechanism observed on T-201-A was internal thinning and external corrosion. Thus, for each damage mechanism was performed calculation for the POF.

Table 2. Design and Operation Data of Tank 201-A

No.	Data	Symbol	Value	Unit
1	Equipment Type		Condensate Storage Tank	
2	Design Code		API 653	
3	Start Date		October 25 1989	
4	Design Pressure	Pd	48	Psig
5	Design Temperature	Td	37.7778	^{O}C
6	Operating Pressure	OP	O	Psig
7	Opertaing Temperature	OT	29.44	^{O}C
8	Outside Diameter	OD	15.24	m
9	Material		SA-283-Gr.C	
10	Height	h	9.500	m
11	Join Efficiency	E	1	
12	Corrosion Allowance	CA	1.5875	mm
13	Specific Gravity	G	0.64	

Table 5 and Table 6 show the damage factor for thinning and external corrosion, respectively. The damage factor for thinning and external corrosion was combined to produced total damage factor. The total damage factor was used to calculate POF for each course in T-201-A shell. Table 7 shows the total POF for asset T-201-A. According to Table 1, the POF for T-201-A falls into category 1.

Calculation of COF was performed to the data of the fluid contained by T-201-A. Table 8 shows the fluid properties in T-201-A. in order to calculate the consequence, according to API 581, 4 different hole size scenarios were made. These scenarios were used to simulate fluid's release rate and mass when failure is expected to occur. Table 9 shows the scenarios of release hole size. The cross-section area for each release hole size can be determined. The next step is to calculate the flow rate release for each release hole size. Table 10 shows the calculates flow rate release. The release volume from leak and from rupture can also be determined, as shown in Table 11 and Table 12, respectively. The release volume can be converted into release mass from leakage and from rupture, as shown in Table 13 and Table 14, respectively.

Table 3. Measurement T-201-A

No.	Component	Max Allowable Stress (psig)	Height from bottom of the shell (inch)	Nominal Thickness (mm)
1	*Course 1*	23600	31.17	9.53
2	*Course 2*	23600	23.13	9.53
3	*Course 3*	26000	15.094	6.35
4	*Course 4*	26000	7.056	6.35

Table 4. Inspection Data T-201-A

No.	Part of Shell	Previous Inspection	Min. Thickness Measured	Last Inspection Date	Min. Thickness Measured
1	Course 1	04-05-2017	9.80	02-07-2020	6.28
2	Course 2	04-05-2017	6.03	02-07-2020	5.95
3	Course 3	04-05-2017	6.50	02-07-2020	5.45
4	Course 4	04-05-2017	5.67	02-07-2020	3.73

Table 5. Damage Factor Internal Thinning T-201-A

Data	Course 1	Course 2	Course 3	Course 4
D_f^{thin}	0.1	0.1	0.1	0.1

Table 6. Damage Factor External Corrosion T-201-A

Data	Course 1	Course 2	Course 3	Course 4
$D_f^{extcorr}$	0.0023	0.00232	0.00266	0.00142

Table 7. POF T-201-A

Data	Course 1	Course 2	Course 3	Course 4
PoF	1.04E-06	1.02E-06	1.03E-06	1.14E-06

Table 8. Fluid Properties

No.	Data	Symbols	Value	Unit
1	Type of Fluid		Water	
2	*Storage Phase*		Liquid	
3	*Molecular Weight*	MW	8.164	kg-mol

No.	Data	Symbols	Value	Unit
4	*Liquid Density*	ρl	62.3	kg/m3
5	*Liquid Viscosity*	μl	0.00000805	N-s/m^3
6	*NBP*		212	^{O}F
7	*Ambient State*		Liquid	
8	*Temperature*	T	132	^{O}F
9	*AIT*		N/A	^{O}F
10	*Constant Presure Specific Heat*	CP	486,500.022	
11	*Discharge Coeficient*	Cd	0.61	

Tabel 9. Relesae Hole Size

Release Hole Number	Release Hole Size	Range of Hole Diameters (mm)	Release Hole Diameter (mm)
1	*Small*	0-6.4	6.4
2	*Medium*	>6.4-51	25
3	*Large*	>51-152	102
4	*Rupture*	>152	406

Table 10. Flow Rate for each Release Hole Size

FLOW RATE (bbl/day)	*W1*	145.454
	W2	2,219.452
	W3	3,6945.894
	W4	585,353.082

Table 11. Release Volume from Leakage

Release Volume from Leakage (barrels)	Bbl^{leak}_1	1,018.178
	Bbl^{leak}_2	8,089.115
	Bbl^{leak}_3	5,278.733
	Bbl^{leak}_4	2,469.051

Table 12. Release Volume from Rupture

Release Volume From A Rupture (Barrels)	$Bbl^{rupture}_1$	10,900.26
	$Bbl^{rupture}_2$	8,089.115
	$Bbl^{rupture}_3$	5,278.733
	$Bbl^{rupture}_4$	2,469.051

Table 13. Release Mass from Leakage

Mass From Leakage (Kgs)	$mass^{leak}_1$	1,018.178
	$mass^{leak}_2$	8,089.115
	$mass^{leak}_3$	5,278.733
	$mass^{leak}_4$	2,469.051

Table 14. Release Mass from Rupture

Mass From Rupture (Kgs)	$mass^{leak}_1$	1,018.178
	$mass^{leak}_2$	8,089.115
	$mass^{leak}_3$	5,278.733
	$mass^{leak}_4$	2,469.051

For each mass release, there was consequence toward flammability and explosive, as well as toxicity. AS shown in Table 8. The fluid contained was water, and therefore, it can be straightforward that the fluid does not exhibit any properties related to flammability, explosive as well as toxicity. Nevertheless, for the sake of the research, the consequence due to failure in asset T-201-A is calculated. The consequence area due to flammability, personal injury due to explosion, as well as toxicity was obtained to be very low, that is 0.97 mm^2 for each. According to Table 1, the COF for T-201-A falls into category A.

The next step is to determine the risk ranking. The POF and COF can be mapped in the risk matrix as shown in Fig. 3 below. From Fig. 3, it can be observed that asset atmospheric storage tank T-201-A possessed low risk. The blue line in Fig. 3 shows the risk target of PT XYZ. It can be observed that the risk of asset T-201-A is far from the risk target.

The remaining life of the asset T-201-A can be calculated using equation (3), as shown in Table 15. For asset T-201-A, the remainning life used is the smallest value of each course, which is 25.07 years in course 4. This is due to the difference in measured thickness value of T-201-A. The measured thickness in T-201-A gets thiner at a considerably faster rate based on historical data from inspections that have been carried out by PT. XYZ.

Table 15. Remaining Life T-201-A

Data		Value	Unit
Tank 201-A	*Course 1*	44.159	year
	Course 2	129.735	
	Course 3	131.513	
	Course 4	25.07	

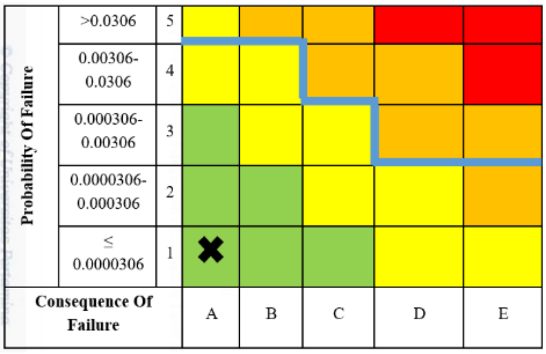

Fig. 3 Risk *Matrix on Storage Tanks*

Corrosion rate may be the cause of the thinning in T-201-A. The type of fluid type greatly affects the risk level in case will affect the corrotion rate value for results POF calculation and will also affect the value of flammable, explosive and toxic consequence for the results of the consequence area (COF) calculation which affect in obtaining the risk level.

4 Conclusion

Based on the discussion of the research study, below is some conclusion:

1. A case study analysis of risk assessment in atmospheric storage tank of PT. XYZ has been conducted using RBI method.
2. The asset under evaluation is T-201-A which is used to store water. The probability of failure (POF) is obtained to be low, that is less than 3.06×10^{-05} failure/year, which fall in category 1.
3. The consequence of failure (COF) due to flammability, explosion, and toxicity of the fluid (water) is also low, that is 0.97 mm^2, which falls in category A.
4. From probability and consequence of failure, the risk possessed by the asset T-201-A can be identified as low risk (1A).
5. The corrosion rate is considered to be a factor that greatly affects POF since it will affect the POF.
6. The impact of corrosion rate can be observed from the measure thickness from the inspection data. The remaining life of atmospheric storage tank T-201-A was obtained to be 25.07 years.

References

[1] Anisatul Umah: Simak, Rincian Hasil Investigasi Kebakaran Kilang Balongan. cnbcindonesia.com. (2021)

[2] Retia Kartika Dewi: Kronologi Kebakaran Tangki di Kilang Pertamina Cilacap> Kompas.com, (2021).

[3] Diva Lufiana Putri: 5 Fakta Kebakaran Kilang Minya Pertamina di Balikpapan yang Menewaskan 1 Pekerja. Kompas.com. (2022).

[3] Wayne B. Geyer: Handbook of Storage Tank Systems (Codes, Regulation and Designs). Marcel Dekker, Inc. New York, Basel. (2000).

[4] American Petroleum Institute (API). Risk Based Inspection API Recommended Practice 580 Third Edition. Washington. D.C: API Publishing Services .(2016).

[5] M. H. Faber, "Risk Based Inspection Maintenance Planning," Risk Based Inspection Maintenance Planning, p. 3. (2001).

[5] American Petroleum Institute (API). Risk Based Inspection API Recommended Practice 580 Third Edition. Washington. D.C: API Publishing Services. (2016).

[6[American Petroleum Institute (API). Risk Based Inspection Methodology API Recommended Practice 581 Adendum 2. Washington. DC: API Publishing Service 2020.American Petroleum Institute. (2020).

[7] Muhammad Faruqi Bin Rahmad: Risk Based Inspection for Atmospheric Storage Tanks.Bachelor Dissertation. Universitas Teknologi Petronas. (2015)