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Quantitative Fire Risk Assessment of Crude Oil Tank at Company A

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ABSTRACT
The oil and gas industry has a high risk of losses due to fire. There have been several fire incidents in the oil industry involving fires in crude oil tanks. The objective of this research is to assess the level of fire risk in Crude Oil Tank T32 at Company. The research method used is to analyze the frequency of fire occurrences using event tree analysis and modeling the consequences of fires using ALOHA software. After conducting frequency analysis and consequence modeling, individual risk and social risk are calculated. Results: Based on the results of consequence modeling, the furthest distance for heat radiation with a 100% risk of death is 84 meters. The largest risk calculation result is in the leaky tank scenario with a hole size of 100 mm with an individual risk value of 1,84 x 10^{-8} and a social risk value of 3,13 x 10^{-7}. The results of the T32 tank fire risk assessment at Company A's oil collection tank facility show that individual and social risks are still within the acceptable risk category according to the UK HSE Risk Acceptance Criteria. Even though the risk of a fire incident is still within acceptable limits, risk control efforts still need to be carried out so that the risk remains within acceptable tolerance limits.

1. Introduction

Fire is a problem that is often faced in Indonesia and other countries. As industrialization develops, the risk of fire increases, especially in the oil and gas sector (Lestari et al., 2021). In the last century, a series of major accidents, such as the Flixborough, Bhopal, and Piper Alpha, have been in the spotlight on the potential dangers posed by the chemical industry and the impact of those hazards on the surrounding communities (FIChemE & Richardson, 2018; Pitblado et al., 1990). In the 2018-2019 period, there were 4 fire cases whose losses were included in the top 20 in the 30 years since 1988 (Robb, 2020).

Some fires in the oil and gas industry involve crude oil tanks. For example, the case of the Huangdao depot fire in Qingdao in 1989 which caused 19 people to die with losses of up to 35.4 million yuan (Dong, 2013; Yuan et al., 2021). In addition, the Gulf Oil refinery fire in Philadelphia in 1975 which lasted for 10 days caused 8 fire brigades to die (Quivik, 2015; Yoshida, 2019).

Facilities that are more than 30 years old have the potential to suffer losses. In the first 10 years of factory operation, most of the losses are caused by operation-related failures, such as not following operating procedures or work permits. As the facility's operating experience grew, the number of losses due to these things decreased. Failures related to mechanical integrity cause 65% of losses. Deterioration in equipment/piping integrity becomes more common as plants age, which can increase the risk of fire.

Company A has a final oil gathering facility, a place where all crude oil is collected before being distributed to the Port for transportation by oil tankers. This failure stores crude oil in the form of heavy oil and light oil which have a risk of burning. Company A's oil collection facility has been operating for more than 50 years, so the potential for losses is quite high.

In order to fulfill compliance with Law No. 1 of 1970, Company A highly upholds the aspect of occupational safety to protect workers, the environment, assets and the reputation of the company. Because this facility is a facility where crude oil flows, this facility is very critical and needs to be kept safe to avoid fires. If there is an operational disruption, the production and distribution of crude oil from this company will result in losses for both the Company and the State.

In the concept of risk management, conducting assessments related to risks that can occur is important to be able to control risks. For this reason, studies related to fire risk are carried out as a basis for risk control. The purpose of this study is to look at the potential for fires in crude oil tanks in companies using ALOHA software.

2. Materials and Methods

This study is a non-experimental quantitative study. Data analysis is processed using software based on possible fire scenarios. This quantitative study framework uses the reference of The Centre for Marine and Petroleum Technology (Sponge, 1999) presented in Figure 1.

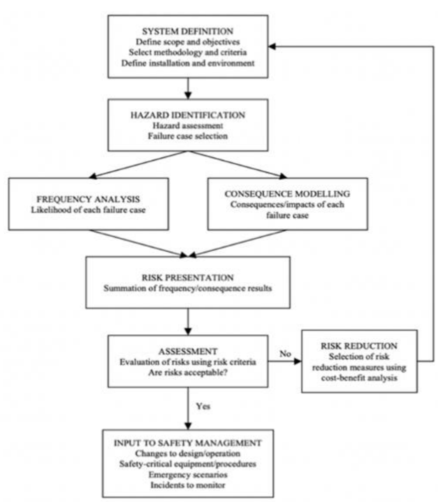

Figure 1 Quantitative Study Framework

Data collection related to the research object is carried out as input data to conduct this quantitative study. The data is in the form of geographic, meteorological data, tank specifications, fuel characteristics, operational process conditions, and the environment around the research object. Then, the researcher identified the fire hazard on the research object (T32 tank). The results of hazard identification continued to be analyzed for frequency analysis and analysis of fire modeling consequences. Event tree analysis is used to analyze the frequency of fires, while ALOHA software is used to analyze the consequences of fire modeling. After conducting frequency and consequence analysis, a risk analysis was carried out by calculating individual risk and societal risk. The concept of as low as reasonably practicable (ALARP) is used to evaluate whether the risk is still acceptable or not. The upper limit of individual risk for ALARP is 1 x 10-3, while the lower limit is 1 x 10-6 (HaSPA, 2012).

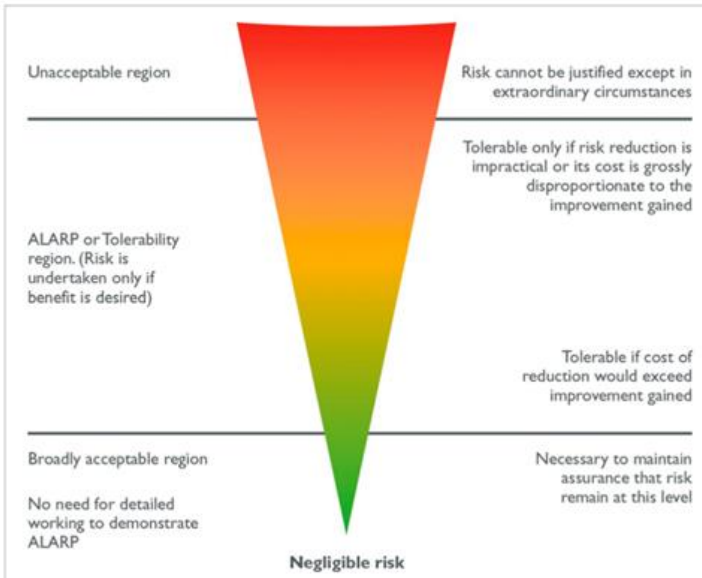

Figure 2 Risk Levels and ALARP (modified from HSE, 1988)

3. Results and Discussions

Company A's Crude Oil Collecting Facility is the largest facility where all crude oil produced is stored before being distributed to customers through a port that is also operated by Company A. The facility, which has an area of 400,000 m2, consists of 16 crude oil collection tanks which are divided into 2 types of crude oil, namely *light oil* and *heavy oil*. This facility operates for 24 hours with 2 *shifts* (morning and night), and the number of workers is 17 people at any time.

The T32 tank is an oil collection tank (hydrocarbon) located at the final crude oil collection facility in Company A. This tank holds crude oil of *the light oil* type, which is a class 1-C flammable liquid based on the category in NFPA 30 (2021). The T32 tank is a *vertical* tank type *atmospheric* tank with a *fixed cone roof* with a height of 17.07 m and a diameter of 90.53 m. The storage capacity of this tank is around 674,840 bbls. This tank is located in an area close to other facilities besides company facilities, such as other company facilities and public facilities. The following is the distance from the T32 Tank and other facilities around it.

Table 1 Distance of the T32 Tank to the Surrounding Facilities

Facilities	Distance (m)

Control Room Building	380
Main Office	540
Fire Station	680
Product Oil Depot Facilities	355
Gas Metering Facilities	600
Highway	655
Residential Areas	800

Fire Hazard Identification

Although there is no history of fires at this facility, the potential danger in the operation of the crude oil collection tank cannot be ignored. The potential for oil spills and fires can occur if not controlled. Process failures such as declining equipment integrity and overpressure or overfilling have the consequence of fuel leakage that has the potential to cause fires that have an impact on workers, communities, the environment, and company assets. The worst possible scenario for the T32 tank that is used as the object of this study is a fire in the embankment (*dike*), which functions as the *secondary containment* of the T32 tank. The identification of this scenario is intended so that the company can ensure that the readiness of this fire control equipment can be met according to its needs.

Table 2 Fire Hazard Identification

Early Events	Cause	Consequences
Leakage	Deterioration of equipment integrity, overpressure, overfilling failure of vibration operation	Pool fire in tank
	Deterioration of equipment integrity, overpressure, overfilling failure of vibration operation	Pool fire in a dike

Analysis of Fire Frequency

Referring to *the Risk Assessment Data Directory* OGP RADD 434-3 of 2010 for the frequency of leaks in *atmospheric tanks*, the frequencies for leaking and ruptured tank failures are presented in Table 3. (OGP, 2010a)

Table 3 Frequency of Leaks

Initiating Event		Hole Size (mm)	Failure Mode	Release Frequency (per tank per year)
Leak (continuous release)	Small	5	Minor	3.0×10^{-4}
	Medium	25	Major	1.0×10^{-4}
	Large	100	Major	1.0×10^{-4}
Cracked (instantaneous release)		> 250	Catastrophic	5.0×10^{-6}

The results of the analysis of the frequency of pool fires using the event tree analysis (ETA) method in the Bevi Risk Assessments version 3.2 – Module B Reference Manual with a probability of direct ignition of 0.065 are as follows (RIVM, 2009).

Table 4 Pool Fire Scenario Frequency Analysis

Scenario		Pool Fire frequency per year
Leak	5 mm	**1,95 x 10^{-5}**
	25 mm	6,5 x 10^{-6}
	100 mm	6,5 x 10^{-6}
Cracked	>250 mm	3,25 x 10^{-7}

Fire Consequence Modeling Analysis

The results of modeling the consequences of the Pool Fire event are presented in Table 5. The heat radiation generated by the *pool fire* incident produces varying exposure distances. This is affected by the size of the leak and the speed of the wind. The release of heat radiation with the worst impact, which is 35 KW/m2, can result in death at a rate of 100% if exposed to humans (OGP, 2010b). The worst consequence value is at a distance of 84 meters, namely a scenario where the tank ruptures (holes of more than 250 mm) with a wind speed of 20 m/s. Referring to Table 5, the distance generated from heat radiation does not affect other facilities presented in Table 1.

Table 5 Results of Modeling the Consequences of Pool Fire Events

Initiating Event	Hole Size (mm)	Wind Speed (m/s)	Thermal Radiation Distance (m)		
			35 kW/m2	12,5 kW/m2	6,3 kW/m2
Leaks (*continuous release*)	5	1B	< 10	< 10	< 10
		5D	< 10	< 10	< 10
		20D	< 10	< 10	< 10
	25	1B	< 10	< 10	14
		5D	< 10	15	19
		20D	**11**	14	17
	100	1B	19	38	56
		5D	29	50	67
		20D	**38**	49	59
Rupture (*instantaneous release)*	>250	1B	52	97	139
		5D	61	108	149
		20D	**84**	111	137

An illustration of the results of modeling the consequences of pool fire events in ALOHA software is shown in Figure 3. The thermal radiation threat zone is displayed with three color contours, namely, yellow, orange and red. The contour shown in yellow indicates a radiation exposure area of 6.3 KW/m2, then the contour shown in orange indicates a radiation exposure area of 12.5 KW/m2, while the contour shown in red (innermost) indicates a radiation exposure area of 35 KW/m2.

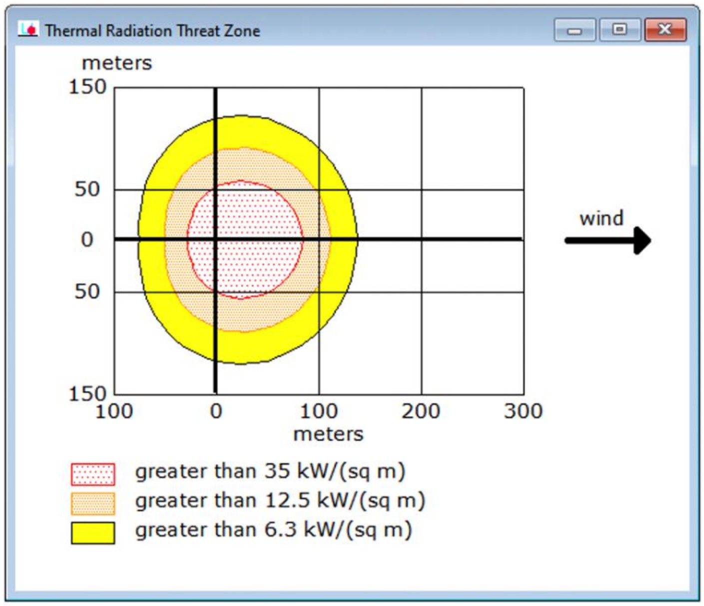

Figure 3 Thermal Radiation Threat Zone yang Dihasilkan Software ALOHA

Risk Analysis

Results from individual risk calculations (CCPS, 1999) presented in table 6. The individual risk value in the leak tank scenario with a hole size of 25 mm is 1.54 x $^{10\text{-}9}$ while for a hole size of 100 mm is 1.84 x 10-8. Then the individual *risk* value in the leak tank scenario with a hole size of 250 mm is 4.50 x 10-9. By looking at the results of this *individual risk* value, the incidence of *pool fires* in the T32 tank shows that it is still within acceptable limits.

Table 6 Individual Risk Calculation Results

Scenario		Area Terdampak (m^2)	Consequence Impact	Fatality Probability	Event Frequency (per year)	Individual Risk (per year)	Conclusion
Leaks	5 mm	0	0	1,95 x 10^{-5}	1,95 x 10^{-5}	0	Acceptable
	25 mm	94,9	2,37 x 10^{-4}	6,5 x 10^{-6}	6,5 x 10^{-6}	1,54 x 10^{-9}	Acceptable
	100 mm	1.133,5	2,83 x 10^{-3}	6,5 x 10^{-6}	6,5 x 10^{-6}	1,84 x 10^{-8}	Acceptable
Cracked	>250 mm	5.538,9	1,38 x 10^{-2}	3,25 x 10^{-7}	3,25 x 10^{-7}	4,50 x 10^{-9}	Acceptable

After calculating individual risks, societal risk calculations are carried out to see the risks that may occur in a community, in this case, the group of workers in facilities that may be affected. The number of permanent daily workers at this facility is 17 people. By looking at the results of the consequence modeling for *pool fire* occurrences, the worst *thermal radiation* value is 35 kW/m2 (which can result in death at a rate of 100% if exposed to humans), then the possibility of affected workers does not exist. However, in this calculation of *societal risk*, it is assumed that these 17 workers are in the worst thermal *radiation* range . The results of the social risk assessment are as follows:

Table 7 Societal Risk Calculation Results

Scenario		**Jumlah Orang**	***Societal Risk***	**Kesimpulan**
Bocor	5 mm	17	0	Negligible
	25 mm	17	$2{,}62 \times 10^{-8}$	Negligible
	100 mm	17	$3{,}13 \times 10^{-7}$	Negligible
Pecah	>250 mm	17	$7{,}65 \times 10^{-8}$	Negligible

The societal risk value in the leak tank scenario with a hole size of 25 mm is 2.62 x 10-8, while for a hole size of 100 mm, it is 3.13 x 10-7. Then, the societal risk value in the leak tank scenario with a hole size of 250 mm is 7.65 x 10-8. Based on these results, the incidence of pool fires in T32 tanks is still within acceptable limits.

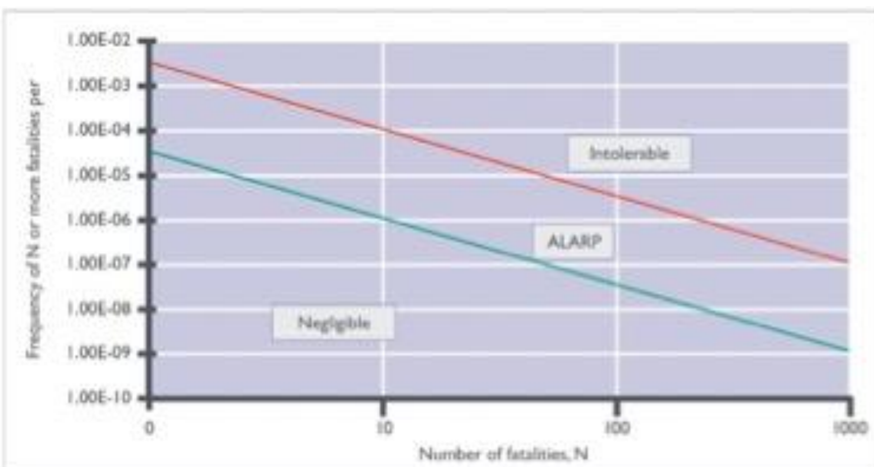

Figure 4 Societal Risk Criteria (modified from NSW Government, 2011)

4. Conclusion

The T32-tank fire risk assessment results at Company A's oil collection tank facility show that individual and social risks are still within the acceptable risk category according to HSE UK's Risk Acceptance Criteria. Although the risk of fire events is still within acceptable limits, risk control efforts still need to be carried out so that the risk is still within acceptable tolerance limits. Some of the efforts that can be made to control risks include identifying hazards in each work process, ensuring that the workers involved have appropriate qualifications and competencies, ensuring that the equipment used is in good condition and in accordance with the work being done, ensuring the completeness of documents in carrying out each work, ensuring the integrity of equipment/instruments in the work process, ensuring the preparedness of emergency resources fire and integrity of the fire protection system, ensuring access control into the facility is carried out properly to maintain safety in the facility, providing education to workers regarding all hazards in the facility, evaluating the work process including contractor performance.

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