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Fire and Explosion Risks at PT X's Crude Oil Storage Facility

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Fire and Explosion Index; crude oil; tank backpile; fire; explosion.

ABSTRACT

Crude oil storage facilities have a potential risk of fire and explosion due to the storage of large quantities of flammable materials. This study aimed to assess the fire and explosion risks associated with the S-01 crude oil storage tank at PT X using the Dow's Fire and Explosion Index (F&EI) method. The research employed a semi-quantitative descriptive approach through field observations, interviews, documentation analysis, and the collection of relevant company data. The analysis results showed a Material Factor (MF) value of 10, a General Process Hazards Factor (F1) value of 1.75, and a Special Process Hazards Factor (F2) value of 3.13, resulting in a Fire and Explosion Index (F&EI) value of 54.78. Based on the Dow classification, this value was categorized as a light hazard level, indicating that the potential fire and explosion risks associated with the tank were relatively low. This condition was influenced by the availability of adequate protection systems, relatively stable operating conditions, and moderate process hazard factors. Nevertheless, continuous facility monitoring, routine inspections, and consistent implementation of safety procedures remain necessary to prevent incidents within the operational area.

INTRODUCTION

Since the beginning of modern oil and gas industrialization in the mid-19th century, the oil and gas industry has played a dominant role in global economic growth, both as a source of energy production and as a major consumer sector. Similarly, in Indonesia, the oil and gas industry, which has been operating for more than 125 years across various working areas and contract regions, has experienced multiple cycles and transformations that require continuous adaptation. Oil and gas industry activities are inseparable from various risks and hazards, particularly those associated with process operations and the storage of chemicals or hydrocarbons that have the potential to cause fires (Adrian, 2026). Fire incidents may result in fatalities, serious injuries, financial losses due to equipment damage and production interruptions, employment impacts, and environmental degradation. According to the World Fire Statistics Bulletin No. 28 issued by The Geneva Association in 2012, fire incidents can cause economic losses equivalent to approximately 1% of global Gross Domestic Product (GDP).

In general, within process industries, including the oil and gas sector, fires are commonly caused by equipment failures that result in leaks or releases of flammable materials from components such as pipes, flanges, valves, vessels, pumps, and storage tanks. These failures and material releases may occur due to corrosion, erosion, pressure and flow fluctuations, external loading, overpressure conditions, thermal fatigue, and other operational factors.

A total of 242 fire accidents have been reported in storage tank areas or material storage facilities across various industries over the past 40 years. The majority of these incidents occurred in oil refineries, oil terminals, and oil collection facilities. Approximately 85% of these accidents involved fires and explosions in storage tanks. Among reported tank accidents, crude oil tanks experienced the highest number of incidents, with 66 recorded cases (Chang, 2005).

Petroleum (crude oil) is a dense brown to black hydrocarbon liquid that is highly flammable. It is formed from organic fossil materials through geological processes occurring over millions of years and is primarily composed of hydrocarbon compounds, particularly alkanes. Due to the lengthy formation process, crude oil is considered a non-renewable energy resource. As a primary energy source, petroleum plays an essential role in supporting modern industrial and economic activities.

Crude oil is classified as a flammable material. According to the National Fire Protection Association (NFPA), crude oil has a flammability rating of 3, indicating a high level of flammability. Furthermore, crude oil generally has a flash point below 60°C (140°F), classifying it as a flammable liquid that requires appropriate storage and handling controls.

Crude oil is generally stored in tanks with designs that vary depending on operational requirements. Storage tanks are available in various sizes and configurations, with designs intended to withstand fluid pressure conditions, minimize leakage and corrosion risks, and manage ventilation and vapor control systems. The most commonly used storage tank type is the vertical cylindrical storage tank, which may range from 10 to 400 feet in diameter. Storage capacities vary widely, from several hundred barrels to several thousand barrels. In certain applications, Very Large Crude Carriers (VLCCs) and Ultra Large Crude Carriers (ULCCs) may also serve as temporary storage facilities. These vessels typically exceed 250,000 deadweight tons and can transport and store more than 2 million barrels of crude oil.

Storage tank fires frequently occur alongside explosions, resulting in significant economic and operational losses. Based on available data, more than 64% of fire incidents occurred in petrochemical plants, petroleum refineries, and storage depots, with approximately 82% of these fires resulting in explosions. Fire incidents most commonly occurred during maintenance, repair, and loading and unloading activities. Approximately 27% of accidents were attributed to human error, including errors during inspection and maintenance activities (Zheng & Chen, 2011).

PT X is one of the companies operating in Indonesia's upstream oil and gas sector. Crude oil produced from production wells is transported through pipelines to temporary storage facilities. The storage process utilizes tanks with specific capacities, creating potential fire and explosion risks associated with crude oil storage operations.

PT X carries out a government mandate to support increased crude oil production in order to meet national energy requirements. In 2024, Indonesia's crude oil production was approximately 635,000 barrels per day, while national crude oil demand reached approximately 1.3 million barrels per day.

Fire and explosion risk assessments are required to ensure safe operations and effective risk management in PT X's crude oil storage facilities. According to the Center for Chemical

Process Safety (CCPS), a hazard refers to physical or chemical characteristics that have the potential to cause harm to workers, the environment, and property (Crowl, 1996). The Dow's Fire and Explosion Index (F&EI) method is one of the widely applied semi-quantitative approaches for evaluating fire and explosion hazards in process industries. This method provides a systematic framework for identifying potential hazards, assessing existing safety measures, and prioritizing risk reduction strategies. By applying this method to the S-01 crude oil storage tank at PT X, this study aimed to provide a comprehensive assessment of fire and explosion risks and develop practical recommendations for risk mitigation.

METHOD

This study employed a semi-quantitative descriptive approach to evaluate the potential fire and explosion hazards associated with the S-01 crude oil storage tank. The tank had a total capacity of 55,000 barrels and was used to store crude oil transported to the Production Collection Center from production facilities, including Collection Stations (SP), Main Collection Stations (SPU), and production wells. The Dow's Fire and Explosion Index (F&EI) method was applied because it is specifically designed to assess fire and explosion hazards in process industries involving flammable materials (Nezamodini ZS, 2017).

The Dow's Fire and Explosion Index (F&EI) 7th edition was selected as it provides a systematic evaluation of potential fire and explosion risks (Gupta, 2003). Previous studies have shown that this method offers a practical and comprehensive approach for estimating process risk and can be applied within a relatively efficient timeframe (Jafari, 2011). Furthermore, the method can support process optimization by providing measurable parameters from technical and economic perspectives (Suardin, 2007).

The data were obtained from two sources: primary and secondary data. Primary data were collected through field observations, documentation, and interviews with personnel involved in facility operations. Secondary data were obtained from operational management records and relevant facility documents in accordance with applicable procedures. The collected data were processed using Microsoft Excel based on the calculation procedures outlined in the 7th edition of the Dow's Fire and Explosion Index (F&EI) method.

RESULT AND DISCUSSION

The S-01 tank located in district 1 of PT X's production area is a storage tank crude oil which has a total capacity of 55,000 barrels. This tank is a tank with a fixes roof type and has a diameter of 34.146 M. This tank is used as storage Raw which comes from all districts 1, both from other Collection Stations and from production wells.

This tank was built in 1957 where in this case it is approximately 69 years old. Until now, the tank is still used for crude oil storage. With oil production declining, the use of tanks has never reached the maximum storage limit.

The tank itself is also equipped with safety equipment such as sprinklers and foam chambers. This safety equipment is connected to the fire extinguishing network/line hydrant. In addition, around the tank there are also several fire monitor.

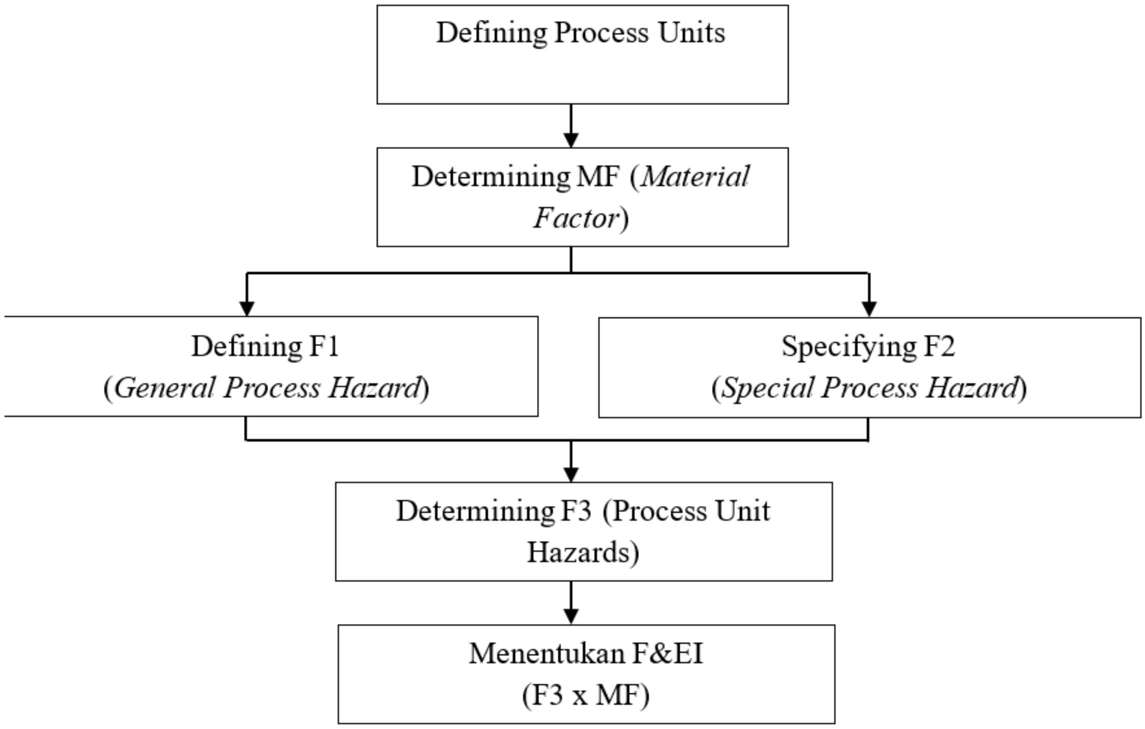

Figure 1 Fire and Explosion Index Determination Scheme (AIChE, 1994)

Based on the guidelines of Dow's Fire and Explosion Index, the first stage in the calculation is to determine the Material Factor (MF) for crude oil, which is obtained at 10. Furthermore, an evaluation of General Process Hazards (F1) and Special Process Hazards (F2) was carried out to determine the amount of penalty factors. The result of multiplication between F1 and F2 results in a Process Unit Hazard Factor (F3). Then, the value of F3 is multiplied by the Material Factor (MF) so that the value of Fire and Explosion Index (F&EI) is obtained

Table 1. F&EI Calculation Results of S-01 Tank (AIChE, 1994)

Material Factor (MF) of Crude Oil					**10**
1	*General Process Hazards*			Penalty Factor	Penalty
	Base Factor			1,00	1,00
	a	*Exothermic Chemical Reactions*		0.3 - 1.25	0,00
	b	*Endothermic Processes*		0.2 - 0.4	0,00
	c	*Material Handling & Transfer (Table 1)*		0.25 - 1.05	0,85
	d	*Enclosed or Indoor Process Units*		0.25 - 0.9	0,00
	e	*Access*		0.2 - 0.35	0,00
	f	*Drainage and Spill Control*		0.25 - 0.5	0,00
	General Process Hazards Factor (F1)				1,75
2	*Special Process Hazards*				
	Base Factor			1,00	1,00
	a	*Toxic Material(s),*		0.2 - 0.8	0,40
	b	*Sub-Atmospheric Pressure (< 500 mm Hg)*		0,50	0,00
	c	*Operation Near In or Near Flammable Range*			
		1	*Tank Farms Storage Flammable Liquids*	0,50	0,50
		2	*Process Upset or Purge Failure*	0,30	0,00
		3	*Always in Flammable Range*	0,80	0,00
	d	*Dust Explosion (See Table 3) Type =*		0.25 - 2.0	0,00

	e	*Pressure (See Fig. 2)*	0.16 - 1.5	0,18
	f	*Lowest Temperature =*	0.2 - 0.3	0,00
	g	*Quantity of Flammables / Unstable Material lb =*		0,00
		1 *Liquids or Gases In Process*		0,00
		2 *Liquids or Gases in Storage*		0,75
		3 *Combustible Solids in Stg*		0,00
	h	*Corrosion and Erosion Rates*	0.1 - 0.75	0,20
	i	*Leakage - Joints and Packing*	0.1 - 1.50	0,10
	j	*Use of Fired Equipment*		0,00
	k	*Hot Oil Heat Exchange System*	0.15 - 1.15	0,00
	l	*Rotating Equipment*	0,50	0,00
	Special Process Hazards (F2)			3,13
3	*Process Unit Hazards Factor (F1 x F2) = F3*			5,48
	Fire and Explosion Index (F3 x MF)			54,78

The base factor in *General Process Hazards* is set at 1.0. Based on the results of the summation of all assessment items, an F1 value of 1.75 was obtained. Meanwhile, items that have a value of 0.00 indicate that no penalty is given to the parameter. The details of the assessment of each item in the General Process Hazards are explained as follows:

1. The penalty on the Exothermic Reaction parameter is not applied because there *is no exothermic reaction* in the Crude Oil storage process.
2. Penalties for endothermic reactions are also not given because there is no endothermic reaction in the *Crude Oil storage process*.
3. In terms of material handling, the S-01 tank is cylindrical and is used to store *crude oil* which is included in the classification of *combustible liquid* with a value of Nf = 2, so it is subject to a penalty of 0.25.
4. On the parameters of the closed process unit, a penalty is not applied because the *crude oil storage area* is designed in an open condition.
5. The area of the facility where the S-01 tank is located is a large open area, has free access and there are two emergency access lanes. In addition, the location is far from crowded centers such as residential areas so it is considered adequate to support the evacuation process and handle emergencies in the event of an incident.
6. The drainage and leak control system in the area of the production facility where the S-01 tank is located has been well designed. However, it has not been completely free from spills. The drainage has been equipped with a control tank, but if there is *a large amount of spill*, the control tank cannot completely withstand the flow rate of crude oil. In this case, a penalty of 0.5 is imposed.

The base factor for Special Process Hazards is set at 1.0. Based on the results of the summation of all assessment items, an F2 value of 3.13 was obtained. Meanwhile, items that have a value of 0.00 indicate that there is no penalty applied to that parameter. The details of the assessment of each item in the *Special Process Hazards* are explained as follows:

1. In the parameters of toxic materials, based on the *National Fire Protection Association*' s standards, *crude oil* has an Nh value of 2 so the penalty applied is 0.4.
2. Penalties for pressure under the atmosphere are not applied because tank1 S-01 operates at atmospheric pressure.

3. In the operating parameters in the flammable range, based on Table 1 item 2.C.1 *crude oil* stored in the S-01 tank has a flash point of 46°C, while the operational temperature of the tank is higher than the flash point which ranges from 60-70°C. Therefore, the penalty for item 2.C.1 is given at 0.5. Meanwhile, items 2.C.2 and 2.C.3 are not subject to penalties as equipment under normal conditions does not operate within the flammable range.
4. The dust explosion penalty is not applied because the material being handled belongs to the combustible *liquid category*.
5. In operational pressure parameters, the S-01 Tank has a normal pressure of 1 atm or about 14.7 psig. The penalty value can be determined by entering the amount of the operating pressure value of 14.7 psig. So that the penalty value is based on the following equation:
   With the value of X = 14.7 psig, the result of the equation is:
   $Y = 0.16109 + ((1.61503 \times 14.7)/1000) - 1.42879\ (14.7/1000)^2 + 0.5172\ (14.7/1000)^3)$
   $Y = 0.184$
   Then the penalty value on the discharge pressure parameter = 0.184
6. The penalty for low operating temperatures is not applied because the operating temperature of the S-01 tank is in the range of 60-70°C. These conditions show that the potential for material damage due to extreme low temperatures is relatively small.
7. In the material quantity parameters, *crude oil* has a heat of combustion (Hc) value of 19×10^3 BTU/lb with the average *crude oil* storage in the S-01 tank being 903254 lb. Based on the *equation of Curve C Figure 4 – combustible liquid*, a penalty value of 0.75 was obtained for item 2.G.2.
8. For the corrosion and erosion parameters, the corrosion rate in the S-01 tank is 0.127. Referring to *the Dow's Fire And Explosive Index* guidelines, this condition is subject to a penalty of 0.2.
9. In the leakage parameters, a penalty of 0.1 is given because potential leaks in the tank piping connections are still possible.
10. Penalties for the use of combustion equipment are not applied because there is no equipment in the S-01 tank area that uses an combustion system.
11. On the operating parameters of the hot oil exchange, a penalty is not given because the medium used by the S-01 tank is water heated through the boiler.
12. Penalties for rotating equipment are not applied because there is no rotating equipment in the S-01 tank area.

Based on the results of the calculation of the F1 and F2 values above, the *value of the Process Unit Hazard Factor* (F3) can be obtained from the multiplication of the two factors. The F3 value obtained is 5.48. Furthermore, the value *of the Dow's Fire and Explosion Index* is calculated by multiplying the value of F3 by *the Material Factor* (MF), so that the *value of the Fire and Explosion Index* (F&EI) is obtained of 54.78. Based on the classification of the hazard level according to *the Dow's Fire and Explosion Index* guidelines, the F&EI value is included in *the light* category. The category of hazard level based on the DOW method refers to (AIChE, 1994).

The Fire and Explosion Index value obtained of 54.78 is included in the light hazard category based on the classification on Dow's Fire and Explosion Index. The results show that the level of potential fire and explosion hazards in the analyzed units is still relatively low. This value indicates that the possibility of damage caused by fire or explosion incidents is estimated to only impact a limited area around the process unit.

The low index value is influenced by several factors, such as the characteristics of the material that are not too dangerous, the relatively stable operating conditions, and the small penalty value in the general process hazards and special process hazards parameters. In addition, the existence of an adequate fire control and protection system also contributes to reducing the level of risk to the unit.

Although it is included in the category of minor hazards, the potential for fires and explosions still needs to be considered. Risks can still arise due to material leakage, equipment failure, power source, or operational errors. Therefore, the implementation of routine inspections, facility maintenance, and supervision of safety systems is still necessary to prevent incidents that can interfere with operations and worker safety.

CONCLUSION

Based on the calculation results using the Dow's Fire and Explosion Index (F&EI) method, the obtained Fire and Explosion Index (F&EI) value was 54.78, which was classified as a light hazard level. The results indicated that the fire and explosion risk level in the evaluated process unit remained relatively low, suggesting that the potential consequences were limited. This index value was influenced by relatively controlled operating conditions, material characteristics with manageable hazard potential, and the availability of adequate safety and control systems. Nevertheless, PT X continued to monitor equipment conditions, conduct periodic inspections, and consistently implement safety procedures to minimize the possibility of incidents within the operational area.

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