Reaktor

p-ISSN 0852 – 0798
e-ISSN 2407 – 5973

Website: http://ejournal.undip.ac.id/index.php/reaktor/

Reaktor, Vol. 26 No. 2, August Year 2026, pp. 1-7

Hydraulic-Based Evaluation of Fire Water System Adequacy for Dike-on-Fire Scenario at Gasoline Storage Tank

Maulida Maghfiroh Izzani Hakim[1*], Marko Ferdian Salim[2], and Annisa Maulida Ningtyas[2]

[1]Applied Master's Program in Occupational Safety and Health, Department of Health Information and Services, Vocational College, Universitas Gadjah Mada, Sleman, Special Region of Yogyakarta, Indonesia, 55281
[2]Department of Health Information and Services, Vocational College, Universitas Gadjah Mada, Sleman, Special Region of Yogyakarta, Indonesia, 55281

[*] Corresponding author: maulidamaghfirohizzanihakim2000@mail.ugm.ac.id

(Received: 1 June 2026; Accepted: 16 July; Published: 10 August 2026)

Abstract

Dike-on-fire incidents in hydrocarbon storage tank facilities have significant escalation potential due to prolonged thermal radiation exposure and adjacent tank involvement. This study evaluated the adequacy of the existing fire water system under a gasoline storage tank dike-on-fire scenario at PT X Refinery using PHAST consequence analysis, firefighting demand calculation, and PIPENET hydraulic simulation. Fire consequence analysis was conducted to evaluate thermal radiation exposure, while firefighting demand and hydraulic analyses were performed based on NFPA and API standards. The simulation results showed that the 12.5 kW/m² thermal radiation contour extended up to approximately 83 m from the fire source, indicating significant fire escalation potential within the tank farm area. The required fire water demand reached 11,665.68 gpm, whereas the existing fire water distribution network was capable of supplying 13,017.50 gpm during simultaneous cooling and firefighting operations. However, the operational foam application capacity of the installed High-Capacity Foam Monitor (HCFM) system resulted in an extended minimum firefighting discharge duration of 83.12 min. Overall, the existing fire water distribution network was hydraulically adequate for the analyzed dike-on-fire scenario, although the operational firefighting capability remained constrained by the installed HCFM system.

Keywords: dike-on-fire; fire water system; hydraulic analysis; PHAST; storage tank fire

How to Cite This Article: Hakim, M.M.I., Salim, M.F., and Ningtyas, A.M., (2026), Hydraulic-Based Evaluation of Fire Water System Adequacy for Dike-on-Fire Scenario at Gasoline Storage Tank, Reaktor, 26 (2), 1 - 7, https://doi.org/10.14710/reaktor.85087

INTRODUCTION

The oil and gas industry is inherently exposed to a high risk of fire due to the handling and storage of large quantities of flammable hydrocarbons (Pramesti et al., 2024). Among the critical facilities in refineries, hydrocarbon storage tanks present a particularly high hazard because they contain volatile and combustible materials that may lead to fires or explosions, resulting in casualties, asset damage, operational disruption, and environmental impacts

(Sotoodeh, 2023). Storage tank fires may further escalate into domino-effect scenarios through thermal radiation and fire propagation to adjacent tanks or process units (Baser & Behnam, 2020). Consequently, effective emergency preparedness and fire protection measures are essential to mitigate escalation and reduce the potential consequences of such incidents.

According to the Directorate General of Oil and Gas, Ministry of Energy and Mineral Resources of Indonesia (2022), hydrocarbon storage tank fires have occurred in several refinery facilities in Indonesia, demonstrating that tank fires remain significant industrial hazards despite the implementation of fire protection systems. At PT X Refinery, one of the critical assets is a gasoline storage tank with an approximate storage capacity of 157,000 barrels. The large gasoline inventory increases the likelihood of prolonged burning, high heat release rates, and fire escalation during an incident. Kwon et al. (2021) reported that gasoline tank fires are particularly difficult to extinguish because of their high burning intensity and prolonged fire duration, requiring substantial firefighting resources. These characteristics highlight the need to assess whether existing fire protection systems are capable of supporting effective firefighting operations under credible large-scale fire scenarios.

Although refinery tank farms are generally equipped with active fire protection systems, including fire water systems, hydrants, monitors, and foam systems, the presence of these facilities does not necessarily ensure effective firefighting performance under specific fire scenarios (Sotoodeh, 2023). Their capability should be evaluated under representative emergency scenarios to verify whether available firefighting resources can effectively support emergency response. In addition, National Fire Protection Association (NFPA) 1620 emphasizes that pre-incident planning should incorporate information on facility hazards, available firefighting resources, and emergency response strategies to support effective incident management (Curless, 2019).

At PT X Refinery, the tank farm is equipped with fire protection facilities, including hydrants, monitors, foam systems, and a fire water distribution network. However, the capability of these systems has not been quantitatively assessed for credible fire escalation scenarios, particularly dike-on-fire scenarios involving gasoline storage tanks. Without such an evaluation, it is difficult to determine whether the existing system can deliver sufficient firefighting flow while maintaining adequate hydraulic performance during emergency response. As noted by Dunn et al. (2017), the absence of quantitative assessments may lead to uncertainty in estimating firefighting resource requirements and response effectiveness in hydrocarbon storage facilities.

Previous studies have investigated tank fire behavior, thermal radiation, and domino-effect escalation in hydrocarbon storage facilities. Khodabakhsh et al. (2026) evaluated tank vulnerability and domino-effect propagation but did not integrate fire consequence analysis with hydraulic analysis to assess the adequacy of fire protection systems. Similarly, Nam et al. (2026) examined firefighting techniques for gasoline tank fires, with emphasis on operational firefighting practices rather than the quantitative assessment of system capability. Collectively, these studies provide valuable insights into fire behaviour and emergency response; however, limited attention has been given to evaluating whether existing fire water systems can simultaneously satisfy firefighting demand while maintaining adequate hydraulic performance under realistic dike-on-fire scenarios involving gasoline storage tanks. To address this gap, this study evaluates the adequacy of the fire water system for a gasoline storage tank under a dike-on-fire scenario by integrating Process Hazard Analysis Software Tool (PHAST) consequence analysis, firefighting demand calculations, and PIPENET hydraulic simulation. This integrated approach provides a quantitative assessment of whether the existing fire water system can reliably supply the required firefighting flow while maintaining adequate hydraulic performance during simultaneous cooling and fire suppression operations.

MATERIALS AND METHODS

This study applied an engineering-based evaluation approach to assess the adequacy of an existing fire water system under a dike-on-fire scenario at a gasoline storage tank facility. The study consisted of fire consequence analysis using PHAST 9.0, firefighting demand calculation based on NFPA and American Petroleum Institute (API) standards, and hydraulic simulation of the existing fire water network using PIPENET software.

Study Object and Fire Scenario

This study was conducted at a gasoline storage tank facility located at PT X Refinery. The evaluated tank was an external floating roof storage tank containing gasoline products with an approximate storage capacity of 157,000 barrels. The tank farm area was equipped with hydrants, monitors, foam systems, fire water distribution pipelines, and fire pumps. The analyzed fire scenario was a dike-on-fire scenario caused by a gasoline spill and ignition within the bundwall area surrounding the storage tank. The scenario dimensions and surrounding equipment configuration were determined based on the actual tank farm layout.

Fire Consequence and Firefighting Demand Analysis

Fire consequence analysis was conducted using PHAST 9.0 to evaluate thermal radiation contours and escalation potential under the analyzed dike-on-fire scenario. The simulation model was developed using technical data of the gasoline storage tank, including tank geometry, inventory volume, operating temperature, and operating pressure, obtained from refinery engineering and operating documents. Site-specific meteorological parameters, including wind speed and ambient temperature, were derived from BMKG data using representative average conditions for the simulation. Gasoline was selected as the hydrocarbon inventory for the simulation, and its relevant physical and thermodynamic properties, including flash point, boiling point, molecular weight, and heat of combustion were automatically retrieved from the PHAST component database after the material was specified. The key simulation input parameters used in the analysis are presented in Table 1.

Firefighting demand analysis was performed based on NFPA 11, NFPA 15, API RP 2001, and API RP 2030 standards by considering cooling water requirements for adjacent tanks and foam application requirements for dike-on-fire scenarios. The required firefighting capacity consisted of cooling water demand, foam solution demand, and water demand for foam application.

According to NFPA 15 and API RP 2030, adjacent tanks exposed to thermal radiation shall be protected using water spray cooling systems. Cooling water demand for adjacent tanks was calculated based on the exposed shell surface area using Equation (1).

$$Q_c = \pi \times d \times h \times r \times C \tag{1}$$

where Q_c is cooling water demand (L/min), d is tank diameter (m), h is exposed tank height (m), r is cooling water application rate (L/min/m²), and C is section coverage factor.

The cooling water application rate used in this study was 4.1 L/min/m² based on API RP 2030 recommendations for hydrocarbon storage tank exposure protection under radiant heat conditions (American Petroleum Institute, 2014).

Foam demand for dike fire suppression was calculated based on NFPA 11 requirements for fixed foam application on diked hydrocarbon liquid fires using Equation (2).

$$V_f = A \times R_f \times C_f \times t \tag{2}$$

where V_f is foam concentrate requirement (L), A is dike surface area (m²), R_f is foam application rate (L/min/m²), C_f is foam concentrate proportion (%), and t is foam discharge duration (min).

The foam application rate used in this study was 6.5 L/min/m² with a minimum discharge duration of 30 min, based on NFPA 11 requirements for foam monitoring protection of diked hydrocarbon liquid fires (NFPA, 2016).

Hydraulic Analysis of the Fire Water System

A hydraulic analysis was conducted to evaluate the capability of the existing fire water system to supply the required firefighting demand during emergency conditions. The evaluated network consisted of fire pumps, ring main pipelines, hydrants, monitors, and foam systems installed in the tank farm facility.

Steady-state hydraulic simulation was performed using PIPENET software to analyze flow rate distribution, pressure distribution, and hydrant hydraulic performance under the selected fire scenario. Hydraulic simulation was conducted under simultaneous cooling and firefighting operations using the required flow demand calculated in the previous firefighting demand analysis.

Hydraulic performance was evaluated based on the available firefighting flow rate, hydrant outlet pressure, and fire pump operating conditions during simultaneous cooling and firefighting operations. The simulation results were then compared with the calculated firefighting demand to determine whether the existing fire water system could maintain the required flow rate and operating pressure throughout emergency response operations, in accordance with the performance criteria specified in API RP 2030.

RESULTS AND DISCUSSION

Fire Scenario and Thermal Radiation Analysis

The analyzed fire scenario involved a dike-on-fire incident at gasoline storage tank D-320-07B located in the Plant Feed and Product Tankage Unit #320 at PT X Refinery. The scenario assumed that an initial rim seal fire, initiated by a lightning strike, escalated into a full surface tank fire and ultimately caused tank failure. The resulting gasoline release accumulated within the surrounding bundwall and ignited, producing a large pool fire that exposed the adjacent storage tanks within the same containment area to thermal radiation. This scenario was selected because it represents a credible worst-case escalation event in which prolonged pool fire exposure may significantly increase cooling water demand and challenge the capability of the existing fire water system.

The PHAST simulation predicted that the dike-on-fire scenario generated thermal radiation extending beyond the burning tank into the surrounding tank farm area. The thermal radiation contours extended beyond the burning tank and reached adjacent gasoline storage tanks D-320-07A and D-320-07C located within the same bundwall. This finding indicates that a fire originating from a single storage tank may escalate into a multi-tank incident if adjacent tanks are not adequately cooled during an emergency response. The predicted thermal radiation contours are presented in Figure 1.

Table 1. PHAST Simulation Input Parameters

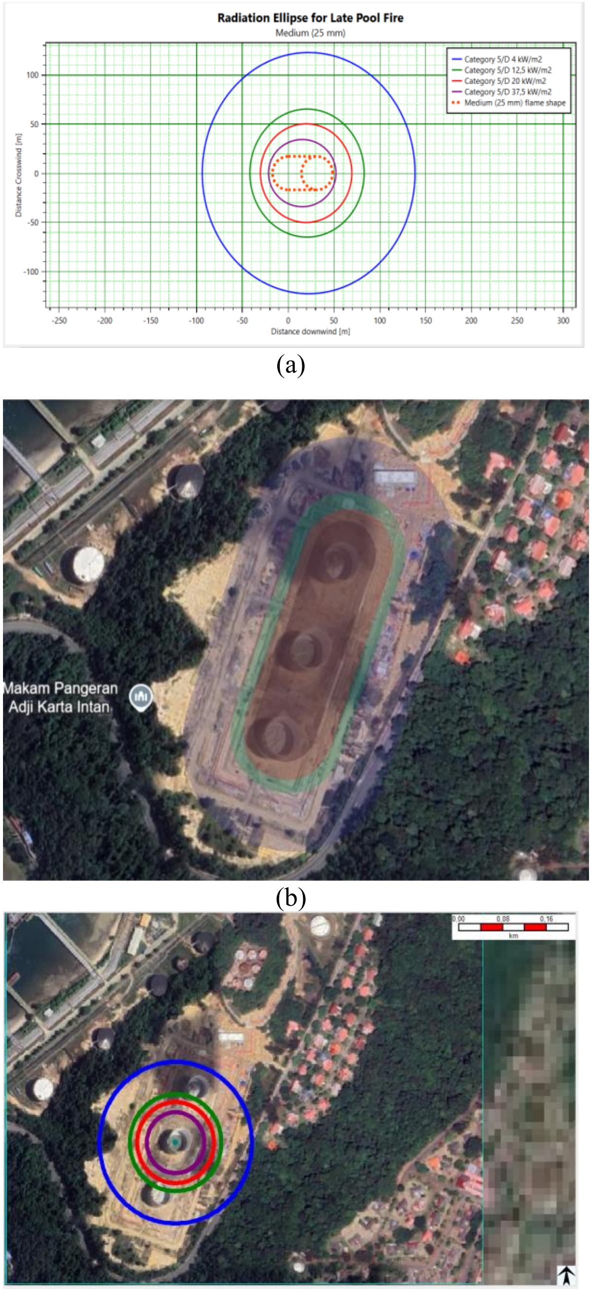
Parameter	Value
Fire scenario	Dike-on-fire
Tank type	External floating roof tank
Stored material	Gasoline
Leak hole diameter	25 mm
Inventory volume	20,905 m³
Operating Temp.	40 °C
Operating pressure	Atmospheric
Flash point	-49 °C
Boiling point	82.23 °C
Molecular weight	91.96 g/mol
Heat of combustion	3.94E+09 J/kmol
Wind speed	5 m/s
Atmospheric stability	Pasquill D
Relative humidity	87.8%
Ambient temperature	29.6 °C
Pool diameter	34.00 m

The predicted thermal radiation distances for each radiation threshold are presented in Table 2. The 12.5 kW/m² contour extended up to approximately 83 m from the fire source, whereas the 20 and 37.5 kW/m² contours were limited to 69.53 m and 52.18 m, respectively. According to Baser and Behnam (2020), the OGP thermal radiation intensity of 12.5 kW/m² represents a level at which prolonged exposure may cause severe damage to process equipment and significantly limit emergency response activities. Therefore, the predicted radiation distances indicate that adjacent tanks located within the affected thermal radiation zone require continuous cooling to reduce thermal loading, maintain structural integrity, and minimize the likelihood of fire escalation during prolonged firefighting operations.

Table 2. Thermal Radiation Level

Radiation Level (kW/m²)	Distance (m)
37.5	52.18
20	69.53
12.5	83.00
5	124.09

The predicted thermal radiation contours demonstrate that prolonged exposure may substantially increase the likelihood of fire escalation within the tank farm. Continuous thermal radiation can progressively increase the thermal loading on adjacent storage tanks, resulting in thermal



(a)

(b)

(c)

Figure 1. PHAST Simulation Result of Thermal Radiation for Dike-on-Fire Scenario

weakening of the tank shell and increasing the probability of fire propagation if cooling measures are not maintained.

Similar observations were reported by Baser and Behnam (2020), who found that prolonged thermal radiation is a primary contributor to domino-effect escalation in hydrocarbon storage facilities. Furthermore, Kwon et al. (2021) reported that large-scale gasoline tank fires are characterized by high heat release rates and extended burning durations, emphasizing the importance of maintaining adequate cooling water supply throughout firefighting operations. These findings demonstrate that the thermal radiation analysis provides the basis for determining the required cooling water demand, which is evaluated in the subsequent firefighting demand analysis.

Firefighting Demand Analysis

The firefighting demand analysis identified a substantial difference between the theoretical firefighting requirements and the operational capability of the existing fire protection system under the analyzed dike-on-fire scenario. Based on the fire consequence analysis, cooling protection was required for adjacent storage tanks D-320-07A and D-320-07C located within the affected thermal radiation zone. The theoretical cooling water demand was calculated as 331.84 m^3/hr for each adjacent tank. However, under the existing fire water spray configuration, the available cooling water capacity was limited to 223.23 m^3/hr per tank.

Similarly, the theoretical foam solution demand required for dike fire suppression was calculated as 188.77 m^3/hr, whereas the installed High-Capacity Foam Monitor (HCFM) system was capable of supplying only 68.14 m^3/hr. This difference reflects the operational limitations of the existing HCFM configuration, whose foam discharge capacity is lower than the theoretical foam application rate required for the analyzed dike-on-fire scenario. Consequently, the achievable water demand for foam application was limited to 2,203.10 m^3/hr, compared with the theoretical requirement of 6,103.72 m^3/hr calculated based on NFPA 11.

Table 3. Fire Water and Foam Demand Summary

Activity	Parameter	Theoretical Req. (m^3/hr)	Existing Capacity (m^3/hr)
Cooling	Adjacent tank cooling water demand	331.84	223.23
Fire fighting	Foam solution demand	188.77	68.14
	Water demand for foam operation	6,103.72	2,203.10
Fire fighting Duration	Minimum discharge time (min.)	30**	83.12
Total Demand	Total fire water demand		2,649.56
	Total foam demand		94.39*

**Total foam demand expressed as foam solution inventory requirement (m^3).*
***Standard firefighting duration assumption prior to adjustment based on existing HCFM operating capacity.*

Consequently, the minimum firefighting discharge duration was extended from the standard 30 min to 83.12 min to maintain continuous foam application under the available HCFM capacity, as summarized in Table 3. Although the lower foam application rate allowed firefighting operations to continue using the existing equipment, the extended discharge duration implies a longer period of thermal exposure for adjacent tanks and places greater demands on the reliability of the fire water supply throughout the suppression operation.

The observed difference between the theoretical firefighting requirements and the available operational capacity reflects the distinction between design-based firefighting demand and the capability of the installed HCFM system. The theoretical foam demand was calculated in accordance with NFPA 11 to represent the application rate required for effective suppression under the analyzed dike-on-fire scenario. In contrast, the operational firefighting capacity was governed by the discharge capacity of the existing HCFM configuration, resulting in a lower achievable foam application rate and a longer discharge duration. Therefore, although the existing equipment could support firefighting operations, it could not achieve the theoretical suppression capacity specified by the design standard.

The prolonged firefighting duration identified in this study also demonstrates the operational challenges associated with large-scale gasoline storage tank fires. Kwon et al. (2021) reported that such incidents are characterized by high heat release rates and extended burning durations, making sustained firefighting operations particularly demanding. Similarly, Baser and Behnam (2020) highlighted that delayed suppression may increase the probability of fire escalation within tank farm facilities. These findings indicate that assessing firefighting demand alone is insufficient to evaluate fire protection system adequacy. It is also necessary to determine whether the existing fire water network is hydraulically capable of delivering the required flow during simultaneous cooling and firefighting operations, as discussed in the following section.

Hydraulic Analysis of Existing Fire Water System

The hydraulic performance of the existing fire water network was evaluated under the analyzed dike-on-fire scenario using the PIPENET model.

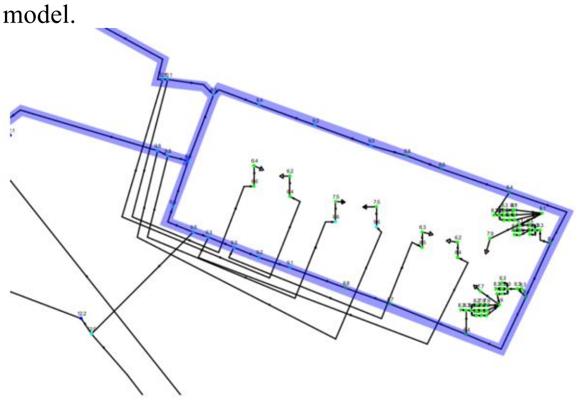


Figure 2. PIPENET Hydraulic Simulation Model

The simulation was performed to verify whether the existing network could hydraulically deliver the firefighting demand determined from the previous analysis during simultaneous cooling and firefighting operations. Figure 2 presents the PIPENET hydraulic simulation model and the corresponding pressure distribution within the existing fire water network, which formed the basis for evaluating flow distribution, hydrant outlet pressure, and overall hydraulic performance.

As summarized in Table 4, the hydraulic simulation predicted a total available fire water flow rate of 13,017.50 gpm, exceeding the calculated firefighting demand of 11,665.68 gpm. In addition, the simulated cooling water supplied to adjacent storage tanks D-320-07A and D-320-07C reached 6,513.25 gpm and 6,504.25 gpm, respectively, both exceeding the required cooling demand. These results indicate that the existing fire water distribution network was hydraulically capable of delivering the required firefighting flow during the design fire scenario.

The hydraulic simulation further showed that pumps G-33-01A, G-33-01B, and G-33-01C operated during the analyzed firefighting scenario, while pump G-33-01D remained on standby. Hydrant outlet analysis indicated that HCFE-01 and HCFE-02 delivered firefighting flow rates of approximately 5,808.2 gpm and 3,925.7 gpm with outlet pressures of 6.97 kg/cm²G and 7.17 kg/cm²G, respectively. These results indicate that the operating pumps were able to maintain sufficient outlet pressure to support simultaneous cooling and firefighting operations throughout the analyzed emergency scenario.

The hydraulic simulation confirmed that the existing fire water distribution network was capable of hydraulically delivering the required firefighting flow during simultaneous cooling and firefighting operations. The available network capacity exceeded the calculated fire water demand, demonstrating that the ring main system, fire pumps, and distribution pipelines were able to maintain the required flow and pressure under the analyzed fire scenario.

Table 4. Hydraulic Analysis Result

Parameter	Required Demand (gpm)	Hydraulic Analysis Result
Adjacent tank cooling (D-320-07A)	5,832.84	6,513.25
Adjacent tank cooling (D-320-07C)	5,832.84	6,504.25
Total fire water demand	11,665.68	13,017.50
HCFE-01 outlet pressure	-	6.97 kg/cm²G
HCFE-02 outlet pressure	-	7.17 kg/cm²G

From the hydraulic perspective, the existing fire water distribution network was capable of delivering the required firefighting flow while maintaining adequate operating pressure during simultaneous cooling and firefighting operations. However, this result should not be interpreted as indicating that the overall firefighting system fully satisfied the operational firefighting demand. While the distribution network could supply sufficient water to the firefighting equipment, the achievable foam application rate remained constrained by the discharge capacity of the installed HCFM system, as discussed in the previous section. This distinction is consistent with API RP 2030, which emphasizes the importance of adequate hydraulic performance in supporting cooling and firefighting operations during hydrocarbon storage tank fire incidents.

The findings of this study demonstrate that the adequacy of a fire protection system should be evaluated from both hydraulic and operational perspective. Although the existing fire water distribution network was hydraulically capable of supplying the required firefighting flow, the operational foam application capacity remained constrained by the discharge capacity of the installed HCFM system. Consequently, the identified limitation was associated with the firefighting equipment configuration rather than the hydraulic performance of the fire water network itself. Similar observations were reported by Sotoodeh (2023), who emphasized that effective fire protection in hydrocarbon storage facilities depends not only on the reliability of the fire water system but also on the capability of firefighting equipment to support suppression operations.

This study evaluated the existing fire water system under a single dike-on-fire scenario involving gasoline storage tank D-320-07B at PT X Refinery. The analysis was based on steady-state hydraulic simulation using the existing fire water network configuration, available pump capacity, and installed HCFM configuration. Consequently, the findings do not account for transient hydraulic behavior, multiple simultaneous fire scenarios, or alternative fire protection system configurations that may occur under different emergency conditions.

Future studies should evaluate additional fire escalation scenarios and alternative firefighting system configurations to assess their influence on both hydraulic performance and operational firefighting capability. Incorporating transient hydraulic simulations and different fire scenarios will provide a more comprehensive understanding of fire water system performance under large-scale storage tank fire incidents.

CONCLUSION

This study evaluated the adequacy of the existing fire water system under a gasoline storage tank dike-on-fire scenario at PT X Refinery by integrating PHAST consequence analysis, firefighting demand calculation, and PIPENET hydraulic simulation. The PHAST simulation showed that the 12.5 kW/m² thermal radiation contour extended up to approximately 83 m from the fire source, indicating significant fire escalation potential and the need for cooling protection of adjacent storage tanks. Firefighting demand analysis indicated that the required fire water demand reached 11,665.68 gpm, while the limited operational capacity of the installed High-Capacity Foam Monitor (HCFM) system extended the minimum foam discharge duration from the standard 30 min to 83.12 min. In contrast, the hydraulic simulation demonstrated that the existing fire water distribution network was hydraulically capable of supplying the required firefighting demand, providing an available flow rate of 13,017.50 gpm, which exceeded the required demand while maintaining adequate operating pressure during simultaneous cooling and firefighting operations. Therefore, the overall system adequacy should be interpreted from two perspectives. Hydraulically, the existing fire water distribution network was adequate to support the analyzed dike-on-fire scenario. Operationally, however, the installed HCFM capacity remained the limiting factor for achieving the theoretical foam application demand. These findings demonstrate that evaluating fire protection system adequacy requires consideration of both hydraulic network performance and operational firefighting equipment capability to support effective emergency response during large-scale storage tank fire incidents.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ACKNOWLEDGEMENTS

This paper was supported by the Applied Master's Program in Occupational Safety and Health, Department of Health Information and Services, Vocational College, Universitas Gadjah Mada, for providing academic guidance and research support throughout this study. Special thanks are also extended to PT X Refinery for providing technical data, operational information, and fire protection system documentation required for the completion of this research.

REFERENCES

American Petroleum Institute, (2014), Application of Fixed Water Spray Systems for Fire Protection in the Petroleum and Petrochemical Industries, 4th ed., API Recommended Practice 2030.

Baser, B., & Behnam, B. (2020). An emergency response plan for cascading post-earthquake fires in fuel storage facilities. *Journal of Loss Prevention in the Process Industries*, *65*(April). https://doi.org/10.1016/j.jlp.2020.104155

Curless, J. (2019). *Develop a Usable and Effective Pre-Incident Planning Process for the Claycomo Fire Department*.

Directorate General of Oil and Gas, Ministry of Energy and Mineral Resources. (2022). Towards Net Zero Emissions While Maintaining Oil and Gas Safety. *ATLAS Keselamatan Migas*, *4*.

Dunn, C. J., Calkin, D. E., & Thompson, M. P. (2017). Towards enhanced risk management: Planning, decision making and monitoring of US wildfire response. *International Journal of Wildland Fire*, *26*(7), 551–556. https://doi.org/10.1071/WF17089

Khodabakhsh, Z., Dolatabad, K. M., Aleahmad, M., & Omidi, L. (2026). A Petri net-based approach for modeling and analyzing the vulnerability of storage tanks under simultaneous fire and explosion hazards. *Computers and Chemical Engineering*, *206*(November 2025). https://doi.org/10.1016/j.compchemeng.2025.109501

Kwon, K., Kim, Y., Kwon, Y., & Koseki, H. (2021). Study on accidental fire at a large-scale floating-roof gasoline storage tank. *Journal of Loss Prevention in the Process Industries*, *73*(November 2020). https://doi.org/10.1016/j.jlp.2021.104613

Nam, S., Cho, Y., Lee, K., Kim, E., Lee, B., & Seo, D. (2026). An empirical study on the fire behavior and emergency response technique in gasoline storage tank. *Journal of Loss Prevention in the Process Industries*, *99*(August 2025). https://doi.org/10.1016/j.jlp.2025.105792

NFPA. (2016). NFPA 11: Standard for Low-, Medium-, and High-Expansion Foam. National Fire Protection Association.

NFPA. (2017). NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection. National Fire Protection Association

Pramesti, D. A., Ardyanto, D., Widajati, N., & Ernawati, M. (2024). Evaluation of Fire Protection System Implementation in A Production Area of Oil and Gas Company, East Java. *Jurnal Keselamatan Kesehatan Kerja Dan Lingkungan*, *5*(1), 20–27. https://doi.org/10.25077/jk3l.5.1.20-27.2024

Sotoodeh, K. (2023). Review of the role of safety engineers in the prevention and mitigation of fires during oil and gas plant design. *Life Cycle Reliability and* Safety *Engineering*, *12*(2), 83–92. https://doi.org/10.1007/s41872-023-00220-y