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Article

Optimization of Fire Hydrant Maintenance to Minimize Fire Incidents on Board MV. HABCO CARINA

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ABSTRACT

Fire safety on board merchant vessels is critical for the protection of crew, cargo, and assets. This study analyzes the optimization of fire hydrant maintenance on the MV Habco Carina, focusing on the gap between planned maintenance and actual operational readiness. Using a qualitative descriptive method, data were collected through 13 months of direct observation, semi-structured interviews, and documentation review. The study reveals significant discrepancies between the Planned Maintenance System (PMS) records and physical conditions; specifically, critical failures in hose couplings, corroded valves, and insufficient pump pressure were identified despite being logged as "compliant." These failures are attributed to a "tick-box" administrative culture, lack of technical competency among deck ratings, and operational time constraints during cargo handling. The study recommends enforcing strict PMS supervision, conducting authentic weekly pressure tests rather than visual checks, and implementing targeted technical training for crew members. These measures are essential to align the vessel's safety standards with SOLAS Chapter II-2 requirements.

1. Introduction

Strict international and national regulations, specifically SOLAS Chapter II-2 and Indonesian Regulation PM 7/2019, mandate the continuous operational readiness of fire protection systems at all times. Despite these regulations, global data from the IMO and Allianz indicate a persistent rise in maritime fire incidents, often attributed to negligence in equipment maintenance (International Chamber of Shipping, 2020; Widiatmaka, 2018). The critical urgency of fire suppression system reliability was evidenced in the 2018 engine room fire on the MV Golden Ocean, where the effective deployment of fire hydrants proved pivotal in controlling the emergency.

However, the operational readiness of these systems relies heavily on the integrity of interconnected components—including pumps, nozzles, valves, and distribution pipes—where a single point of failure can render the entire system ineffective (Fadillah, 2020; Nugroho et al., 2022). While previous studies have extensively discussed the technical specifications of fire extinguishing equipment, a significant research gap remains regarding the discrepancy between administrative compliance and the technical reality of maintenance in the field. Frequently, maintenance is performed merely as a documentary formality without adequate physical verification, leading to latent failures that are only detected during emergencies.

This study responds to this issue by conducting a case study on the MV Habco Carina, a bulk carrier transporting high-risk coal cargo. Preliminary observations indicate a risk of system failure due to irregular maintenance schedules and a lack of crew technical knowledge, which threatens the reliability of active fire protection mechanisms (Chasenda et al., 2024; Viardhana et al., 2025; Wilastari & Wibowo, 2021). Therefore, this study aims to: (1) evaluate the actual condition of the fire hydrant system on the MV Habco Carina; (2) identify the technical and operational constraints hindering routine maintenance execution; and (3) formulate a systematic maintenance optimization strategy to ensure compliance with safety standards and protect both the crew and corporate assets from fire risks.

2. Literature Review

2.1 Maintenance Strategy in Maritime Safety

Maintenance is defined not merely as a repair activity, but as a strategic combination of technical and managerial measures designed to ensure equipment remains in optimal working condition and complies with international standards (Widiatmaka, 2018). In the context of maritime safety, maintenance is mandatory under SOLAS requirements to guarantee equipment readiness during emergencies (Viardhana et al., 2025). Contemporary strategies prioritize preventive maintenance—scheduled interventions to forestall failures and extend equipment life cycles—over corrective maintenance, which is reactive and undertaken only after a breakdown occurs (Setiawan & Permana, 2025). Neglecting preventive protocols leads to the rapid degradation of critical components such as valves and piping; this not only compromises the system's effectiveness during fire crises but also results in significant financial losses and operational disruptions (Chasenda et al., 2024).

2.2 Critical Components of Fire Hydrant Systems

The fire hydrant system serves as a critical fixed installation designed to deliver high-pressure water for manual fire suppression (International Chamber of Shipping, 2020). Its operational reliability relies entirely on the functional integration of the following key components:

1. **Fire Pumps:** These are the primary mechanisms for transporting seawater to the distribution system. To ensure redundancy, regulations dictate that cargo vessels exceeding 500 GT must be equipped with at least two independently driven fire pumps capable of maintaining sufficient pressure (Prasutiyon et al., 2024).
2. **Fire Main and Valves:** The piping network distributes water to various discharge points. Hydrant valves serve as the critical interface for the crew; failure in these valves due to corrosion or lack of lubrication can prevent the connection of hoses, rendering the system useless (Nugroho et al., 2022).
3. **Hoses and Nozzles:** Fire hoses are flexible conduits designed to withstand

pressures up to 20 bar. They are paired with dual-purpose nozzles that allow operators to switch between a "jet" stream for distance and a "spray" pattern for cooling and crew protection. Blockages or leaks in these components directly reduce the effective reach of water during suppression efforts (Santiko & Tazani, 2021).

2.3 Regulatory Standards and System Classification

The installation and maintenance of fire hydrant systems are strictly governed by SOLAS Chapter II-2, Regulation 14, which mandates that "fire-fighting systems and appliances shall be kept in good working order and readily available for immediate use." This regulation underscores that the system must be capable of delivering continuous water pressure from the engine room to the upper decks to control emergencies effectively (Wilastari & Wibowo, 2021; International Chamber of Shipping, 2020). Operationally, these systems are classified based on their environmental exposure:

1. Indoor Hydrants: Installed in enclosed spaces such as accommodation areas and engine rooms. While shielded from weather, they require regular verification to ensure accessibility in confined zones (Nugroho et al., 2022).
2. Outdoor Hydrants: Located on open decks and cargo areas. These function as robust standpipes but are highly susceptible to corrosion from the marine environment. Therefore, they require rigorous inspection of materials to ensure durability and accessibility during external fires (Prasutiyon et al., 2024; Santiko & Tazani, 2021).

3. Research Methodology

3.1 Research Design and Setting

This study employs a qualitative descriptive approach to investigate the maintenance and operational readiness of fire hydrant systems, aiming to provide a comprehensive understanding of the phenomenon within its natural maritime setting (Anggito & Setiawan, 2018). The research was conducted on board the MV Habco Carina over a 13-month period, from August 4, 2023, to September 21, 2024. This extended duration was deliberately chosen to ensure data adequacy and

saturation, allowing the researchers to observe the full cycle of maintenance routines under various operational conditions—including anchorage, sea voyages, and high-tempo cargo handling operations.

3.2 Informant Selection and Data Collection

To gather comprehensive non-numeric data, respondents were selected using a purposive sampling technique based on their direct responsibility and involvement with the vessel's safety equipment. The three key informants included:

1. The Chief Officer (Mualim I): Selected as the head of deck operations responsible for overall maintenance scheduling and compliance.
2. The Third Officer (Mualim III): Selected as the designated Safety Officer directly responsible for the inspection and upkeep of fire-fighting appliances.
3. The Able Seaman (Jurumudi): Selected to represent the deck ratings who execute the physical maintenance tasks and operate the hydrants during fire drills.

Data from these informants were collected using three primary techniques:

1. Direct Observation: Monitoring the actual physical condition of hydrant components and witnessing maintenance workflows during operations (Hasibuan et al., 2023).
2. Semi-Structured Interviews: Extracting insights regarding operational constraints, crew competency, and maintenance culture (Haydar Hadziq et al., 2024).
3. Documentation: Systematically reviewing daily work logs, Planned Maintenance System (PMS) reports, and photographic evidence of equipment conditions (Amrullah et al., 2022; Hasan, 2022).

3.3 Data Validity and Analysis

To ensure the rigor and validity of the research, source triangulation was applied. This strategy cross-verified information obtained from different sources; for example, claims made during interviews regarding regular maintenance were validated against written PMS logbooks and the actual physical condition

of the hydrants observed in the field.

The data analysis framework utilized the interactive analysis model proposed by Miles and Huberman, which proceeds through three distinct stages: data reduction (filtering relevant maintenance discrepancies), data display (presenting findings in structured tables), and conclusion drawing. This continuous process ensures that the analysis remains rigorous and reaches data saturation, thereby producing a valid formulation for optimizing fire hydrant maintenance on the vessel (Hakim, 2020).

4. Results and Discussion

4.1 Observation: Physical Degradation and Operational Failures

Field observations conducted on the MV Habco Carina revealed critical physical degradation across the fire hydrant system. As shown in Figure 1 and Figure 2, specific mechanical deficiencies included leaking hose couplings, loss of elasticity in rubber gaskets, and heavily corroded valve handwheels that hindered manual operation. These physical conditions constitute a direct violation of SOLAS Chapter II-2, Regulation 14.2.1.2, which mandates that fire-fighting systems must be kept in good working order and readily available for immediate use.



Figure 1. Fire Hydrant has experienced a decline in quality

The impact of these maintenance failures was empirically demonstrated during the fire drill on April 10, 2024. The system failed to generate sufficient water pressure to reach the simulated fire targets on the main deck. Furthermore, the nozzle mechanisms were found to be obstructed by sediment and lacked necessary lubrication. This confirms the findings of Chasenda et al. (2024), who noted

that minor component neglect—such as a lack of greasing—directly correlates to total system failure during emergencies. The observed pressure loss indicates that the vessel is effectively operating on a "breakdown maintenance" basis rather than the required preventive regime.



Figure 2. Maintenance Fire Hydrant

The study also identified significant gaps in crew competency, particularly among deck ratings, who demonstrated limited technical understanding of troubleshooting procedures for hydrant malfunctions. While general fire drills were conducted, they lacked specific training on diagnosing pressure losses or rectifying nozzle blockages, leading to a superficial state of readiness (Santiko & Tazani, 2021). Consequently, the combination of technical deterioration and insufficient human resource capability compromises the vessel's overall safety architecture, necessitating a rigorous overhaul of both maintenance discipline and training protocols to ensure the system functions effectively when required (Wilastari & Wibowo, 2021).

LAPORAN BULANAN PEMERIKSAAN HYDRANT

NAMA KAPAL : MV HABCO CARINA
WAKTU : 15 MAY 2024

PERAWATAN	YA/TIDAK	KETERANGAN
1. PEMERIKSAAN SIKLUS FIRE HYDRANT	YA	
2. PEMERIKSAAN KONDISI VALVE HYDRANT	YA	
3. PEMERIKSAAN KONDISI NOZZEL HYDRANT	YA	
4. PEMERIKSAAN KONDISI HOSE HYDRANT	YA	
5. PEMERIKSAAN KONDISI BELT/KAJANG FIRE HYDRANT	YA	
6. PEMERIKSAAN AREA SEKITAR FIRE HYDRANT BERKAITAN DENGAN BERSIH DAN BEBAS HALANGAN	YA	
7. PEMERIKSAAN GASKET HYDRANT	YA	
8. PEMERIKSAAN (MENCEK) HYDROMETER/FLUID BAHAN (DI BUKA TUTUP)	YA	
9. PEMERIKSAAN PERIKSAAN HYDRANT	YA	
10. PEMERIKSAAN TEKNIK/TIM HYDRANT LINE	TEKNIK	
11. LUBRIKASI WATER TIGHT TEST	TEKNIK	
12. PEMERIKSAAN PIPA FIRE MAIN HYDRANT	TEKNIK	
13. TEST ALARM AIR DARI SETAP HYDROMETER/FLUID TEST	TEKNIK	
14. PEMERIKSAAN SIKLUS FIRE HYDRANT	TEKNIK	
15. PEMERIKSAAN TEKNIK FIRE PUMP	TEKNIK	
16. PEMERIKSAAN SIKLUS FIRE HYDRANT	TEKNIK	

Figure 3. Monthly Report

4.2 Interviews: The Human Element and Management Gaps

Interviews with key personnel revealed that the root causes of these technical failures are deeply rooted in organizational and competency issues. Rather than presenting repetitive narratives, the key thematic findings from the interviews are summarized in Table 1.

Table 1. Thematic Analysis of Interview Findings

Informant	Key Constraints Identified	Impact on Maintenance
Chief Officer (Mualim I)	Operational Priority: High intensity of cargo handling operations forces the rescheduling of maintenance.	Critical "Fire Line Pressure Tests" are frequently delayed or cancelled to prioritize commercial operations.
Third Officer (Safety Officer)	Administrative Culture: A "tick-box" culture prevails where PMS logs are filled to satisfy audits rather than reflecting reality.	Discrepancy between reported compliance and actual corroded condition; limited spare parts availability.
Deck Rating (Jurumudi)	Competency Gap: Lack of technical training on troubleshooting specific equipment (valves/nozzles).	Crew panic during drills when valves jam; inability to perform immediate field repairs due to lack of knowledge.

As highlighted in Table 1, the Chief Officer confirmed that commercial pressure often overrides safety protocols, leading to the deferral of critical pipe de-scaling and pressure testing. Meanwhile, the Deck Ratings admitted to a lack of confidence in operating the equipment due to insufficient technical drills, supporting the argument by Santiko and Tazani (2021) regarding the necessity of competency-based training.

4.3 Documentation: The Administrative Operational Gap

A comparative review of the Planned Maintenance System (PMS) Monthly Reports (Figure 3) and the actual visual evidence (Figure 4) reveals a significant administrative gap.

Documented Status: The logbooks consistently record the condition of hydrants, hoses, and nozzles as "Good" or "Normal," with all weekly inspection checkboxes marked as "Completed."

Actual Status: Physical verification

showed rusted valve spindles, seized couplings, and dry-rotted hoses.



Figure 4. Trying Fire Hydrant

This discrepancy indicates that the PMS is being treated as a clerical formality ("tick-box exercise") rather than a technical assurance tool. This practice violates the ISM Code (International Safety Management), which requires that non-conformities and defects be reported and corrected. The administrative compliance masks the latent failures of the system, creating a false sense of security (Widiatmaka, 2018).



Figure 5. Cleaning Deck

4.4 Data Analysis

This study utilizes the Miles and Huberman methodological framework—encompassing data reduction, display, and conclusion drawing—to evaluate the maintenance efficacy of fire hydrants onboard the MV. Habco Carina. The analysis reveals a critical dichotomy between the theoretical standards of preventive maintenance outlined in Chapter II and the actual operational realities recorded in Chapter IV. As evidenced by the data presentation, the implementation of the Planned Maintenance System (PMS) is characterized as non-routine, with essential activities frequently omitted, standing in direct contrast to theoretical requirements which mandate strict adherence to preventive and corrective schedules to ensure equipment reliability. This systemic inconsistency highlights a failure to translate academic

maintenance protocols into practical maritime application.

Technical observations derived from the data reduction phase indicate that physical degradation is a primary consequence of these procedural lapses. Specific findings include leaking hose couplings, clogged nozzles, and stiff valve handwheels caused by insufficient lubrication, all of which contribute to water pressure levels that fail to meet operational standards. These mechanical deficiencies are exacerbated by administrative weaknesses, particularly incomplete logbook documentation that fails to record repair follow-ups. The analysis suggests that the root cause of these issues is not inherent equipment failure, but rather a lack of discipline in executing weekly physical inspections and insufficient oversight by the Third Officer regarding the vessel's safety assets.

Using the Miles and Huberman interactive analysis model, the data was reduced and synthesized to compare the *Actual Condition* against *Theoretical Standards*. This analysis is presented in Table 2.

Table 2. Data Presentation

Aspects Analyzed	Actual Condition	Theoretical Analysis (Chapter II)
Schedul Treatment Fire hydrant	No routine, some PMS activities are missed	It should be carried out preventively and correctively according to the schedule for Maintaining the reliability of the tool
Hose and nozzle condition	Hose leak, Nozzle clogged	Must checked weekly; Physical Treatment Prevents Failure Function According to SOLAS, the pressure must be enough for Reach the farthest point of fire
Water pressure on the fire pump	Not up to standard	Regular training required and clear division of tasks
Crew readiness	Some do not understand Technical Maintenance Procedures	

Furthermore, the study identifies human resource competency as a significant barrier to maintenance optimization. A portion of the crew lacks a comprehensive understanding of technical maintenance procedures, as safety drills tend to prioritize suppression simulations rather than the technical readiness and testing of the equipment itself. To address the research problems formulated in Chapter I, the conclusion advocates for a holistic optimization strategy involving rigorous PMS enforcement, weekly pressure testing, and enhanced technical training for the crew. These measures confirm that the preventive maintenance theories discussed in Chapter II are strictly relevant and necessary for aligning the vessel's safety standards with SOLAS regulations.

4.5 Discussion

The study reveals that the fire hydrant maintenance system on the MV Habco Carina is currently suboptimal. The findings demonstrate a clear deviation from the preventive maintenance theories advocated by Setiawan and Permana (2025). Instead of preventing failures, the vessel's maintenance regime has degraded into a reactive approach, where repairs are only attempted after a component fails during a drill.

The primary impediment is the conflict between Operational Tempo and Safety Culture. As noted by the Chief Officer, the intense workload during cargo operations creates a barrier to routine maintenance. However, this contradicts SOLAS Chapter I, which implies that a ship is unseaworthy if its safety equipment is not functional, regardless of commercial schedules.

Furthermore, the "tick-box" administrative culture identified in Section 4.3 represents a critical management failure. This aligns with Widiatmaka (2018), who argued that effective ship management requires valid data. When the PMS logs are falsified or filled without inspection, the shore-based management is unaware of the need for spare parts (gaskets, valves), exacerbating the scarcity of resources mentioned by the Third Officer.

To resolve these issues, the optimization strategy must move beyond simple technical repairs. It requires a managerial overhaul:

1. Enforcement of PMS: The Third Officer must be empowered to conduct honest

inspections without fear of reprisal for reporting defects.

2. Scheduling: Critical maintenance tasks (like pressure testing) should be scheduled during sea voyages rather than port stays to avoid conflict with cargo operations.
3. Competency: Training must include "technical troubleshooting" (e.g., how to unjam a valve) rather than just "operational use."

5. Conclusion

The study concludes that the maintenance of fire hydrant systems on the MV Habco Carina is currently suboptimal, primarily due to a significant disconnect between the Planned Maintenance System (PMS) documentation and the actual physical condition of the equipment. While administrative logs indicate compliance, physical degradation such as corroded valves, leaking hoses, and insufficient pump pressure persists. This discrepancy indicates that maintenance is largely treated as a clerical formality ("tick-box exercise") rather than a technical assurance measure, leading to violations of SOLAS Chapter II-2 standards regarding operational readiness.

The root causes identified are twofold: the prioritization of commercial cargo operations over safety drills, which limits the time available for preventive maintenance, and a lack of technical troubleshooting competency among the deck crew. Consequently, the vessel effectively operates on a reactive maintenance basis, where defects are often only addressed after equipment failure occurs during drills.

To optimize the system and ensure the safety of the crew and assets, this study recommends a strategic managerial overhaul:

1. Operational Rescheduling: Critical maintenance tasks, particularly fire line pressure tests and de-scaling, should be formally rescheduled to be conducted during sea voyages rather than during high-intensity port stays. This resolves the conflict between commercial demands and safety obligations.
2. Empowered Oversight: The role of the Third Officer must be strengthened to prioritize authentic physical verification over administrative logging. A "no-blame" reporting culture should be

encouraged to ensure defects are reported honestly rather than hidden.

3. Technical Competency Training: Drills must evolve from simple operational deployment to include technical troubleshooting scenarios (e.g., clearing nozzle blockages or unjamming valves) to ensure the crew is self-reliant during actual emergencies.

By implementing these measures, the vessel can transition from a culture of administrative compliance to one of genuine safety culture, ensuring that the fire hydrant system remains reliable not just on paper, but in the face of real maritime emergencies.

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