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Optimizing the Use and Maintenance of "Dry Powder" Fire Extinguishers for Fire Suppression on the MT. Pangkalan Brandan

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ABSTRACT

Fire extinguishers are very important to ensure the safe operation of the ship and must meet the applicable regulations, in accordance with the objectives of the Safety of Life at Sea (SOLAS), contains one of the international conventions which contains Operational Readiness and Maintenance of fire extinguishers. fire extinguishers. Fire on board a ship is a serious threat that requires quick and effective handling to prevent major losses. A dry powder type fire extinguisher (APAR) is one of the main solutions in dealing with fires in the maritime environment. However, the effectiveness of APAR depends on optimal use and maintenance. This research aims to optimize the use and maintenance of dry powder ship type APARs in preventing the above fires. The research method involves field surveys on several ships to practice the use and maintenance of APARs. In addition, statistical analysis is used to identify factors that influence APAR performance.

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INTRODUCTION

Maritime safety is a crucial aspect regulated internationally through the Safety of Life at Sea (SOLAS) standards, which establish strict requirements regarding the availability, type, and periodic testing of portable fire extinguishers (PFEs) (Olsen, 2023). On board ships, the risk of fire is extremely high due to the presence of flammable fuels, complex electrical systems, and confined spaces. Efforts to maintain the readiness of fire extinguishers are a key factor in protecting assets and lives, especially when ships are operating on the open sea far from external assistance (Hossain, 2025; Robert, 2025).

However, on-site observations indicate that the risk of fire remains high due to poor equipment maintenance and crew negligence in fulfilling their responsibilities (K. Liu et al., 2025; Tesha, 2018). Although modern ships are equipped with automated systems, fire extinguishers often fail to function properly because they are neglected and not properly maintained. The gap between the

availability of equipment and its operational readiness often results in small fires failing to be contained and escalating into major fires that are difficult to control (Dunn et al., 2017).

The importance of crew understanding and the proper functioning of equipment was demonstrated in the incident involving the KM Bukit Raya in April 2024, where the crew's swift action using a fire extinguisher successfully put out the fire without any loss of life. This incident underscores that the strategic placement of equipment and technical understanding of its use are key to early prevention. This is the rationale behind the need for an in-depth study on the optimization of fire extinguishing equipment, particularly dry powder types, to ensure the reliability of safety systems on board ships.

This study aims to formulate measures to optimize the use and routine maintenance procedures for dry powder fire extinguishers on the MT. Pangkalan Brandan. The primary focus includes improving the effectiveness of crew training and establishing a systematic schedule for periodic inspections and maintenance. With these measures, it is hoped that daily to monthly maintenance procedures can be carried out effectively as a preventive measure to ensure that fire extinguishers are always in ready-to-use condition when facing an emergency.

METHOD

Research Design

This study employs a qualitative method with a descriptive approach to gain an in-depth understanding of social and technical phenomena. A descriptive design was chosen to depict real-world conditions in the field without manipulating variables. The primary focus of the study is to provide a comprehensive overview of the optimization of the use and maintenance of dry powder fire extinguishers based on data collected during a 12-month sea training period aboard a ship.

Data Collecting Techniques

Research data is categorized into two types: primary data and secondary data. Primary data is obtained directly through three methods:

1. Interview: Using a pre-prepared set of questions to gather information from deck and engine room crew members.
2. Daily Observation: The researcher directly participates in daily activities on board the ship, particularly during routine fire extinguisher maintenance performed by informants.
3. Observation Records: Collecting facts from ship inventory lists, maintenance reports, and international regulations such as SOLAS and NFPA to verify the accuracy of field data.

Data Analysis Techniques

The data analysis techniques used in this study were conducted interactively and continuously, following the steps developed by (Sugiyono, 2019). The process began with the objective collection of research data derived from interviews, observations, and documentary studies conducted onboard the vessel. Once the data was collected, data reduction was performed to summarize, select key elements, and simplify the raw data into information that focused more on significant themes related to fire extinguisher optimization. The final stage is data presentation, where the researcher organizes the results of this reduction into descriptive narratives, tables, or diagrams to present the research findings in a structured and systematic manner, thereby facilitating the drawing of accurate conclusions.

RESULTS AND DISCUSSION

Overview of the Research Location

The MT. Pangkalan Brandan is an oil product tanker with a gross tonnage (GT) of 14,458 tons and a length overall (LOA) of 157.50 meters. As a vessel for distributing petroleum products such

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as RON 90, RON 92, and crude oil, it operates with an average trip duration of four days. The vessel is crewed by 26 personnel divided between the deck and engine departments. Given the highly volatile and flammable nature of the hydrocarbon cargo it carries, MT. Pangkalan Brandan has a high-risk profile that demands stringent occupational safety standards and fire protection systems. The physical appearance and structural profile of the vessel are documented in Figure 1.

Figure 1. MT. Pangkalan Brandan Vessel
Source: Author's documentation (2025)

Operationally, the vessel has several critical fire risk points, including the cargo deck, pump room, engine room, manifold, and mooring station. These areas are highly vulnerable to potential hazards such as cargo leaks, mechanical friction, flammable vapors, and heat sources from electrical installations in the engine room.The detailed distribution and exact layout of portable fire extinguishers within these high-risk zones are illustrated in Figure 2.

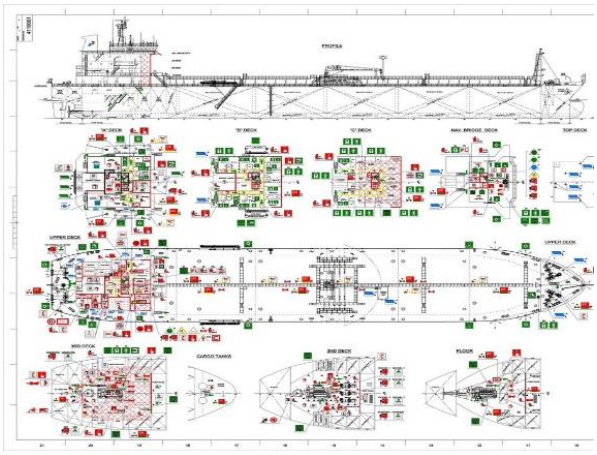

Figure 2. Layout of Portable Fire Extinguishers on Board a Ship
Source: Field observation (2025)

These specific and challenging working conditions make the MT. Pangkalan Brandan a highly relevant research site for evaluating the effectiveness of the placement, use, and routine maintenance procedures for dry powder fire extinguishers as an initial protective measure in addressing emergency situations.

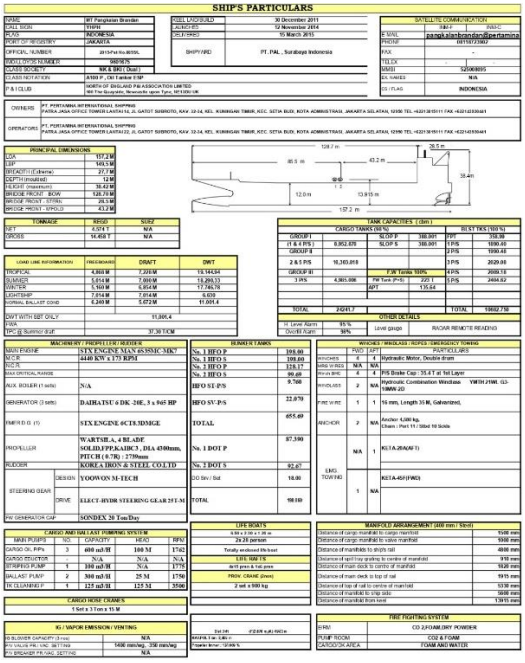

Figure 3. Ship's Particular of MT. Pangkalan Brandan
Source: Field observation (2025)

Analysis of Current Condition and Distribution of Dry Powder Fire Extinguishers on MT. Pangkalan Brandan

Based on direct observations aboard MT. Pangkalan Brandan, the author documented the actual condition of Dry Powder Fire Extinguishers and the prevailing maintenance practices. The findings demonstrate that while daily and monthly maintenance programs are implemented with commendable discipline, potential risks to the effectiveness of the Dry Powder remain specifically regarding chemical compaction and

the cleanliness of hoses and nozzles. However, based on the comparative evaluation, the actual distribution of the fire extinguishers does not fully match the vessel's official evacuation and fire safety plan. Field observations identified several discrepancies, such as relocated units and unmapped extinguishers in certain high-risk zones, which differ from the approved structural drawing.

The comprehensive results of these observations and current maintenance practices are detailed in Table 1. As shown in Figure 4, a crew member is seen directly inspecting a 4 kg SERVO ABC Powder DCP extinguisher mounted in its bracket, verifying the safety pin, seal, and valve condition as part of the routine monthly check.

Figure 4. Development and Inspection of Portable Fire Extinguishers
Source: Field observation (2025)

A critical aspect of fire safety compliance is ensuring that the physical placement of fire extinguishers corresponds exactly to the vessel's approved evacuation and fire safety plan. During the field survey aboard MT. Pangkalan Brandan, the author cross-referenced the actual locations of all Dry Powder Fire Extinguisher units against the official fire safety drawing.

The assessment revealed that while the majority of units are correctly positioned, several discrepancies exist: certain high-risk areas including sections of the engine room access and the cargo pump room vicinity contained units that had been relocated without updating the official plan, while at least two positions indicated on the evacuation drawing were found to be unoccupied at the time of inspection. These gaps represent a potential non-conformity under SOLAS Chapter II-2 and ISM Code requirements, which mandate that fire-fighting appliances be maintained in the positions designated in the vessel's approved safety plan. As illustrated in Figure 5, the crew is seen gathered at the fire extinguisher station during a group inspection, confirming the physical presence and readiness of the units at their designated locations.

Figure 5. Fire Extinguisher Station Review by Crew Members
Source: Field observation (2025)

To verify operational readiness beyond static inspection, a fire drill was conducted aboard MT. Pangkalan Brandan. The drill encompassed both the deployment of portable Dry Powder Fire Extinguishers and the activation of the deck-mounted fire monitor (fire cannon). The exercise was coordinated by the Master and supervised by the Chief Officer, with participation from all deck and engine department crew members. The drill served as a practical verification that both equipment operability and crew competency are maintained at the level required by the vessel's Safety Management System (SMS).

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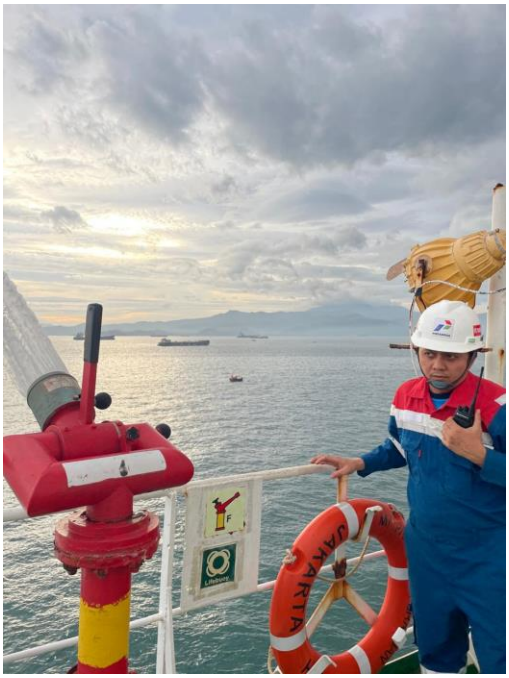

Figure 6. Officer Coordinating Fire Drill via Radio Communication on Deck
Source: Field observation (2025)

Figure 7. Deck Fire Monitor
Source: Field observation (2025)

Based on the observations, the condition of the dry powder fire extinguishers (DRY CHEMICAL POWDER) on the MT. Pangkalan Brandan generally complies with established maintenance procedures: the cylinders are in their brackets, the seals and pins are in place, and the pressure gauges are in the green zone. However, potential issues were identified regarding the storage environment, namely ship vibrations and deck humidity, which can cause the powder to compact and settle within the cylinders (Gkouvas, 2024). Nozzle cleanliness is also a concern, as debris can block the powder discharge path. These conditions can reduce response speed and extinguishing effectiveness when the DRY CHEMICAL POWDER is activated.

In summary, the Dry Powder Fire Extinguishers aboard MT. Pangkalan Brandan are in a generally satisfactory condition from a maintenance standpoint; however, the identified discrepancies between the physical distribution of units and the approved evacuation and fire safety plan require corrective action.

It is recommended that the vessel's Safety Officer conduct a formal reconciliation between field conditions and the official fire safety drawing, update the plan to reflect current unit placements, and ensure that any relocated units are repositioned or that the plan is formally amended through the Company's document control procedure. Additionally, periodic anti-compaction measures such as inverting and shaking extinguisher cylinders during monthly inspections should be standardized to mitigate the risk of powder settling due to vessel vibration and humidity.

Table 1. Field Observation Results of Dry Powder Fire Extinguishers on MT. Pangkalan Brandan

No	Observation Item	Field Findings	Technical Remarks
1	Dry Chemical Powder Locations	Located at the cargo deck, manifold, pump room, and mooring stations.	Placement complies with fuel fire risk area standards.
2	Physical Condition of Cylinders	All cylinders are secured in brackets, seals are intact, and safety pins are available.	No cylinders were displaced or obstructed during daily observations.
3	Pressure Indicator	Gauges on all units are in the green zone.	Indicates operational readiness during daily inspections.
4	Weight Check	Several powder units were re-weighed during monthly inspections.	No weight loss > 10%—indicating no significant loss of extinguishing agent.
5	Hose / Nozzle	Hoses and nozzles were visually inspected.	No cracks found, but several nozzles were slightly dirty and required cleaning.
6	Internal Cylinder Condition	Not directly inspected during daily observations.	Internal inspections are only conducted during 6-month or annual service schedules.
7	Environmental Conditions	Storage areas on the deck are exposed to ship surface heat and high humidity.	High potential for powder compaction (caking) if not shaken/inverted regularly.

Analysis of Crew Perceptions and Maintenance Practices: Interview with the Third Officer

According to the Third Officer, the vessel's current Standard Operating Procedure (SOP) for fire extinguisher maintenance lacks precise operational criteria. While it generally outlines checking pressure gauges and checking brackets, it does not explicitly mandate specific frequencies for dry powder agitation (shaking) or establish contingency schedules when voyages are busy. This structural omission leads to an execution that deviates from international safety standards, specifically SOLAS Chapter II-2 Regulation 14.2.2, which requires rigid compliance with manufacturer guidelines regarding chemical compaction prevention.

The researchers conducted brief interviews with the ship's Third Officer (the officer responsible for routine safety matters) to understand perceptions and practices regarding the maintenance of dry powder fire extinguishers. The summary of the interview results is presented in Table 2.

An interview with the Third Officer reinforced the insights gained from observations. According to him, the powder cylinders are shaken to keep the powder loose, but this is often delayed during busy voyages. This indicates that while formal procedures exist, operational constraints (crew workload) can hinder optimal implementation. Additionally, he noted that the frequency of fire drills is less than ideal, particularly for the use of DRY CHEMICAL POWDER; thus, even though fire extinguishers are available, their potential effectiveness in real-life situations may not be maximized because the crew's skills have not been honed frequently enough.

Table 2. Interview Results with Third Officer regarding Dry Powder Maintenance

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No	Interview Aspect	Field Findings	Technical Remarks
1	What are the procedures for inspecting Dry Powder fire extinguishers on the ship?	"Daily inspections are conducted by the duty officer per the SMS checklist, covering seals, pins, pressure, and positioning. Monthly checks are usually done by the Bosun or myself, including shaking the cylinders to prevent powder compaction."	Daily and monthly procedures are compliant with regulations. Shaking the cylinder is a critical action to prevent reduced effectiveness of the Dry Chemical Powder.
2	Are there any obstacles in performing the cylinder shaking process?	"Sometimes, especially during busy trips. Shaking might be delayed for a day or two, but we strive to keep it within the monthly schedule."	Potential for schedule negligence exists, which could affect readiness. A stricter schedule control system is required.
3	What is the physical condition of the Dry Powder units during inspections?	"Generally, the cylinders are in good condition; brackets and seals are secure. No heavy corrosion. However, some nozzles get dirty due to humid and dusty deck conditions."	Physical condition is good, but nozzle cleanliness needs improvement to avoid the risk of blockage.
4	How do you check the cylinder weight or the powder content?	"For Dry Chemical Powder, we don't weigh them daily. Weighing is typically done during monthly checks and when the service company arrives every six months."	Weighing follows monthly standards. However, internal monitoring could be enhanced to reduce full reliance on third-party services.
5	Based on your experience, how effective is the use of Dry Powder fire extinguishers?	"Dry Powder is our top priority for small fires in deck areas because it quickly interrupts the fire reaction and is easy to use."	Dry Chemical Powder is proven effective as a first response in open areas like the cargo deck and manifold.
6	Are the crew members proficient in using fire extinguishers during drills?	"Generally yes, but I believe the frequency of drills should be increased, especially those specifically for Dry Powder units since they are rarely used in real conditions."	Drill frequency can still be optimized to improve crew preparedness and response.
7	What is your view on the	"It's quite good, following	Routine maintenance is

	current fire extinguisher maintenance program?	SMS and SOLAS. However, port facilities sometimes limit the time for annual servicing, so it can feel a bit rushed."	ongoing, but external factors (port turnaround time) may affect the quality of major services.
8	What are your recommendations for improving Dry Powder readiness on board?	"Perhaps adding units in the forward mooring area and ensuring the shaking is done on time. Also, drills should be more frequent for new ratings."	Supports research recommendations regarding additional units and increased discipline in maintenance scheduling.

Based on the results of observations and interviews, the researchers synthesized the data to identify problem parameters and formulate practical improvement measures. This analysis aims to ensure the reliability of dry powder fire extinguishers through systematic optimization solutions, as outlined in Table 3.

Table 3. Data Analysis and Optimization Strategies for Dry Powder Maintenance

No	Problem Parameter	Existing SOP (MT. Pangkalan Brandan)	Data-Driven Analysis	Optimization Solution (Recommended Actions)
1	Dry Powder Compaction	- Standard monthly visual check of pressure gauge. - No mandatory schedule or specific crew assigned for cylinder inversion/shaking.	Observation: Humid environment and vibrations increase compaction risk. Interview: Inverting/shaking is occasionally delayed.	- Establish stricter SOPs for shaking Dry Chemical Powder cylinders (daily + monthly checklists). - Assign specific responsibility to the Bosun/Ratings for regular shaking. - Utilize digital reminders (PMS) to ensure shaking schedules are not missed.
2	Hose / Nozzle Clogging	- External visual inspection for physical cracks. - No specific protocol for cleaning residue after drills or maritime dust exposure.	Observation: Nozzles are dirty due to dust and deck moisture.	- Schedule more frequent nozzle cleaning (e.g., monthly inspection + after drills). - Add detailed visual inspection procedures for hoses & nozzles in the maintenance plan. - Train crew on correct cleaning methods following IMO A.951(23) guidelines.
3	Extinguisher Operational Readiness	- Fire safety equipment status is logged manually in paper	SOLAS II-2/14 Regulation: Equipment must be ready for use at	- Increase crew awareness regarding readiness obligations (routine briefings). - Integrate extinguisher

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		logbooks. - Routine checks focus heavily on expiration dates rather than physical readiness under high-stress voyage schedules.	all times; however, interviews show delayed shaking.	inspections into the PMS with digital logs & completion markers. - Conduct routine internal audits to ensure SOP compliance.
4	Post-Service Internal Condition Verification	- Extinguishers returned from shore-based servicing are accepted immediately without verification.	Interview: No internal verification mechanism post-service; potential risk of corrosion or content loss.	- After six-monthly / annual service, perform internal verification: re-weigh contents, perform internal visual inspection (if possible). - Create verification reports and archive them in the ship's logbook. - Coordinate with service providers for detailed service reports and certificates per IMO A.951(23) guidelines.
5	Crew Skills in Using DRY CHEMICAL POWDER	- General fire drills are carried out monthly following standard shipboard routines. - Drills rarely include practical, hands-on deployment or specialized handling of Dry Chemical Powder units.	Interview: Drill frequency is lacking; new crew members lack experience.	- Increase the frequency of specific DRY CHEMICAL POWDER fire drills (e.g., 2-3 times/month). - Simulate realistic fire scenarios (such as spills at the manifold). - Evaluate performance after drills and provide feedback and additional training. - Create onboarding training for new ratings covering the use and maintenance of DRY CHEMICAL POWDER.

From a regulatory perspective, the maintenance and readiness of portable fire extinguishers (PFE) on board must align with SOLAS requirements and IMO guidelines (Hossain, 2025; Olsen, 2023):

1. SOLAS Chapter II-2 Regulation 14 mandates that fire extinguishers must be "maintained ready for use" and subject to periodic testing and inspection.
2. A maintenance plan must be available on board and include fire extinguishers as an integral part of the fire protection system.

3. IMO Resolution A.951(23) ("Improved Guidelines for Marine Portable Fire Extinguishers") provides guidelines for the inspection, cleaning, marking, and pressure testing of portable extinguishers, such as Dry Powder types.
4. MSC.1/Circ.1432 ("Revised Guidelines for the Maintenance and Inspection of Fire Protection Systems and Appliances") also recommends systematic inspection schedules and documentation.

Based on this, while onboard practices generally align with regulations, several gaps have emerged: such as delays in monthly shaking/agitation (based on observations & interviews), a lack of internal verification following shore-based servicing, and the potential for clogging and powder compaction that are not always regularly inspected in accordance with IMO guidelines.

Identification of Operational Challenges and Regulatory Gaps

Based on observations and interviews with the Third Officer of the MT. Pangkalan Brandan, the use of dry powder fire extinguishers has not been optimal due to environmental factors and accessibility issues. Field findings indicate that nozzles are frequently clogged by deck dust or moisture, and units are obstructed by other equipment, which directly violates the principle of SOLAS II-2 Regulation 14 regarding equipment readiness (Zisimopoulos, 2016). Additionally, there is a gap between the IMO MSC.1/Circ.1432 standard and onboard practices, particularly regarding the discipline of routinely shaking the powder to prevent compaction, which can hinder the initial fire suppression process.

Strategy for Enhancing Equipment Readiness and Crew Competency

Optimization efforts are focused on integrating rigorous maintenance and increasing the frequency of training. Concrete steps include incorporating cleaning and cylinder shaking schedules into the Planned Maintenance System (PMS) and ensuring that fire extinguisher zones are free of obstructions. In parallel, crew capabilities are enhanced through increased drill frequency (2–3 times per month) and simulations for new crew members in accordance with IMO guideline A.951(23) (Weldon, 1983). This comprehensive strategy is summarized in the following table 4.

Table 4. Optimization of Dry Powder Fire Extinguisher Usage

No	Usage Aspect	Field Findings	Regulatory Compliance	Existing SOP	Analysis	Optimization Efforts
1	Extinguisher Readiness	Extinguishers obstructed, dirty nozzles	SOLAS II-2/14	No nozzle cleaning protocol	Hinders emergency response	Clear access zones, proper signage, nozzle cleaning
2	Discharge Effectiveness	Powder compaction	MSC.1/Circ.1432	No mandatory cylinder shaking.	Reduced powder flow	Scheduled shaking/agitation in the PMS
3	Crew Competence	Irregular drills	SOLAS II-2/15	No drill backup schedule.	Crew unready for emergencies	Drills 2–3 times per month, realistic simulations

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4	Extinguisher Selection	New crew members often confused	IMO A.951(23)	No specific color-coding.	Risk of incorrect usage	Color coding/marking & onboarding training

Optimizing the use of dry powder fire extinguishers thus emphasizes three key aspects: improving equipment condition, complying with international regulations, and enhancing crew competence (Trefný et al., 2022). How are routine maintenance and inspections of dry powder fire extinguishers conducted on board? - Observations indicate that dry powder fire extinguisher maintenance activities on board have followed the company's SMS standards; however, several critical aspects still need to be strengthened. Daily checks are already being performed, but cylinder pressure readings have not been consistently documented. Monthly inspections also revealed delays in shaking the cylinders, which risks causing the fire extinguishing powder to compact.

IMO Regulation A.951(23) and SOLAS Chapter II-2 Regulation 14 emphasize the importance of routine inspections, nozzle cleanliness, pressure checks, and documentation. However, the vessel has not yet conducted post-service internal verification, even though this step is necessary to ensure that the cylinder weight, seal condition, and pressure meet standards after handling by the service company (Asalina, 2018).

Table 5. Routine Maintenance and Inspection of Dry Powder Fire Extinguishers

No	Maintenance Aspect	Field Findings	Regulation	Existing SOP Gaps	Analysis	Optimization
1	Daily Inspection	Visual pressure check only	SOLAS II-2/14	No daily logging required.	No pressure trend monitoring	Daily pressure logbook entry
2	Monthly Inspection	Delayed shaking, dirty nozzles	MSC.1/Circ.1432	No mandatory shaking protocol.	Risk of clogging/blockage	Nozzle cleaning & Bosun supervision
3	6-Monthly Inspection	No internal verification by crew	IMO A.951(23)	Immediate acceptance post-service.	Undetected service errors	Post-service internal verification
4	Annual Inspection	Limited service time	IMO A.951(23)	No specific inspection checklist.	Inconsistent pressure levels	Third Officer verification checklist
5	Storage	Humid/da	FSS Code	No deck	Cylinder	Relocatio

		mp areas		exposure guidelines.	corrosion risk	n of units, use of desiccant packs
6	Documentation	Lack of detail in PMS	MSC.1/Circ.1432	No standardized digital logging.	Incomplete maintenance history	Digital PMS integration

Maintenance optimization focuses on scheduling cylinder shaking during PMS, adding nozzle cleanliness inspections, improving record-keeping, and conducting post-service verification to ensure fire extinguishers are always ready for use at any time. Additionally, enhanced oversight of PMS implementation must be consistently carried out by authorized personnel to ensure every maintenance step is strictly followed according to procedure. This supervision is crucial to ensure no schedules are missed, no fire extinguisher components are overlooked, and all inspection findings can be addressed promptly if any abnormalities are detected (Zhang et al., 2024). Consequently, the maintenance system becomes more structured and capable of maximizing fire extinguisher readiness to handle fire emergencies (Z. Liu et al., 2007; Yuan et al., 2021).

CONCLUSION

Optimizing dry powder fire extinguishers (APAR) on the MT. Pangkalan Brandan requires the integration of disciplined physical maintenance and enhanced crew competency to meet SOLAS and IMO standards. The study concluded that the main challenges lie in the limited accessibility of the units on deck, the risk of powder compaction due to infrequent shaking, and the lack of drill frequency for the crew, particularly new personnel. As corrective measures, it is recommended that fire extinguisher storage locations be reorganized to ensure unobstructed access, that shaking and nozzle cleaning procedures be incorporated in detail into the Planned Maintenance System (PMS), and that the intensity of operational training be increased to ensure equipment readiness and crew response speed in the event of a fire emergency.

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