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Bulk Grain Fumigation at Sea: Preventing Phosphine Explosions and Handling Incident

In the maritime transport of bulk grain, phosphine (PH_3) fumigation is a standard practice for controlling storage pests. However, improper operations can easily trigger severe fire and explosion risks. Recently, a bulk carrier insured through our company experienced an uncommon yet highly cautionary phosphine flash/explosion incident in a cargo hold while transiting the Black Sea. Based on the findings of the casualty investigation, this article provides a sharing for shipowners across three dimensions: cause analysis, loss prevention practice, and evidence preservation.

According to the expert report issued by professional fire investigators, the casualty manifested as a sudden, dense emission of white smoke from the hatch cover perimeters lasting approximately 20 seconds. Although no severe structural damage was sustained, the event represents a classic instantaneous ignition of phosphine gas accumulation that had reached its explosive limits. The core causation comprises three main factors: First, the fumigant was applied in an overly concentrated manner. Instead of being distributed evenly according to product specifications, the chemical tablets/pellets were piled up at the bottom or along the aft boundary of the hold; this dense local concentration caused intense exothermic reactions that reached the auto-ignition point of phosphine. Second, a non-explosion-proof duct centrifugal fan (specifically model ERA PRO Mars GDF 200) was installed inside the hold, where mechanical friction, electrical sparks, or hot surfaces generated during its operation readily introduced an ignition source. Third, the affected cargo hold was loaded to 100% capacity, leaving minimal ullage space at the top. Under limited air availability, phosphine gas rapidly accumulated and reached its lower explosive limit (LEL) of 1.6% to 1.8%.

To prevent similar incidents, shipowners must enforce rigorous loss prevention measures during daily operations. First, the vessel must strictly verify the qualifications and application plans of port fumigation contractors. Designated personnel should be appointed to supervise the uniformity of chemical application, strictly prohibiting the piling of fumigants or placing them adjacent to bulkheads and fans to eliminate localized overheating at the source. Second, if air recirculation systems are required during the voyage, all fans and electrical apparatus inside the cargo hold must be certified explosion-proof; uncertified portable equipment should never be accepted. Furthermore,

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gas monitoring must be rigorously conducted in accordance with the IMO *Revised Recommendations on the Safe Use of Pesticides in Ships Applicable to the Fumigation of Cargo Holds* (MSC.1/Circ.1264/Rev.1). Phosphine concentration checks should be carried out every 4 hours for the first two days of fumigation, and every 8 hours thereafter, across the engine room, accommodation spaces, and boundary spaces to ensure navigational safety.

Should a flash explosion or abnormal sound occur in transit, the Master and crew must immediately undertake comprehensive evidence preservation to protect the shipowner's legal rights and prepare for subsequent liability allocation and cargo loss claims. Crew members should promptly export VDR data, logbooks, and engine telegraph records covering the period before and after the event, while preserving full CCTV footage capturing the incident (e.g., the complete process of white smoke venting at 42°38'N, 033°55'E in the Black Sea). Meanwhile, the vessel must periodically measure and log the external surface temperatures around the hatch coamings and bulkheads, carefully maintaining temperature monitoring sheets. Regarding physical evidence, hatch covers and their sealing materials (such as expandable foam and sealing tape) must remain intact and unopened; the scene should not be cleared until P&I survey representatives and independent fire experts board the vessel for inspection. Any chemical residues and fan equipment must be photographed and physically secured. Following the incident, a Letter of Protest (LOP) should be issued immediately to agents, charterers, and shippers, accompanied by a properly completed Marine Casualty Report. Finally, prior to opening hatches at the discharge port, arrangements should be made—subject to practical feasibility—to test residual toxic gas concentrations in the presence of representatives and experts from all interested parties. Once hatches are opened, cargo condition should be closely monitored, representative samples drawn, and draft surveys along with vessel constant accurately verified to establish the scope of liability.

In conclusion, the key to preventing and responding to in-transit fumigation casualties in bulk grain carriage lies in proactive prevention and documentation. To assist shipowners and crew members in quickly grasping essential guidelines during routine operations and emergency situations, key takeaways are summarized below:

1. **Compliance of Explosion-Proof Equipment**: Strictly prohibit the use of any uncertified portable electrical equipment inside cargo holds. Ensure that fumigation recirculation fans and associated wiring fully comply with explosion-proof safety standards.

2. **Uniform Application & Continuous Monitoring**: On-site crew must strictly supervise fumigation contractors to ensure even distribution of chemicals, preventing auto-ignition caused by localized overheating. Implement routine in-transit gas concentration monitoring as required.

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3. **Preservation of Physical Evidence In Situ**: Do not rush to clean up the cargo hold scene after an incident. Maintain the original condition of hatch cover seals and tape, and preserve chemical residues and fan equipment for expert forensic analysis.

4. **Extraction of Audiovisual and Navigational Data**: Immediately export CCTV video, VDR data, deck and engine logbooks, and temperature logs pertaining to the incident to ensure the integrity and reliability of electronic evidence.

5. **Legal Procedures & Joint Surveys**: Promptly issue a Letter of Protest (LOP), and coordinate joint gas testing and sampling at the discharge port prior to hatch opening with P&I Club representative and independent expert to inspect and sample-taking.

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