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15. Supplementary Notes

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16. Abstract (200 words or less)

The U.S. Coast Guard sponsored this project to assess control measures (technological advancements as well as safety management systems) for preventing or mitigating the impacts of fuel oil or lube oil spray fires on board vessels, particularly in the engine room. For this purpose, we identified a number of proposed control measures to prevent/mitigate the impacts of spray fires, and then we evaluated the reduction in risk that can be expected from the implementation of each measure. As part of our evaluation, we identified many sources of relevant incident investigation reports. These sources provided a total of 143 fires caused by releases of fuel oil/lube oil; of these 9 are known to have resulted in fatalities, and another 8 are known to have resulted in personnel injury.

Our research findings substantiated several (and refuted a few) previous findings/beliefs regarding spray fires. In addition, our investigation resulted in 18 feasible, practical control measures (recommendations) to reduce risks associated with fuel oil/lube oil spray fires in engine rooms. The first 12 recommendations address specific changes to 1) existing fuel oil/lube oil equipment and systems and 2) management issues. The next three recommendations address more significant changes to fuel oil/lube oil equipment, and they are presented for new (or significantly modified) ships. We also identified two areas that require additional research and development efforts, and we developed two recommendations to address these areas. Finally, we determined that much of the risk associated with fuel oil/lube oil spray fires stems from deficiencies in (or lack of) safety management systems. That is, the root cause of these incidents is generally the absence of, neglect of, or deficiencies in management systems.

This report consists of three volumes. Volume I contains a summary of these practices. Volume II consists of Appendix A: MISREP Events and Associated Event Trees Characterization Tables; Appendix B: MSIS Events. Volume III consists of Appendix C: LMIS Events; Appendix D: Nippon Kaiji Kyokai (NK) Events; Appendix E: TSB Events; Appendix F: MIIU Events; Appendix G: NTSB/MAR-95/04 Events; Appendix H: Preliminary Recommendations; Appendix I: Qualitative Analysis of Oil Spray Incidents; Appendix J: Evaluation of the Impact of Preliminary Recommendations; Appendix K: Resumes of Hazard Evaluation Team Members; and Appendix L: June 16-17, 1997, Trip Report.

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SUMMARY

The purpose of this project was to help the United States Coast Guard (Coast Guard) assess control measures for preventing or mitigating the impacts of fuel oil or lube oil spray fires on board vessels, particularly in the engine room. The control measures of interest included technological advancements as well as safety management systems.

Our investigation approach consisted of eight research steps, including assessment of current practices for controlling risks of spray fires and extensive review of spray fires that have occurred worldwide on board vessels. As presented in this summary and discussed in detail in Sections 3.7 and 4 of the report, our research findings substantiated several (and refuted a few) previous findings/beliefs regarding spray fires. In addition, our research evaluated the reduction in risk that can be expected from the implementation of each proposed control measure to prevent/mitigate the impacts of spray fires.

One of the principal activities of this project was to identify a large number of incident investigation reports that could be used to provide insights into the causes of fires and potential options for frequency reduction and/or consequence mitigation. For this purpose, we identified many sources of relevant incident investigation reports: the Coast Guard; the U.S. Marine Safety Information System; Lloyd's Maritime Information Services Limited; the Japanese classification society Nippon Kaiji Kyokai; the Transportation Safety Board of Canada; the Marine Incident Investigation Unit, Inspector of Marine Accidents, Australia; and the U.S. National Transportation Safety Board.

Overall, these sources provided a total of 182 incident records. Of these, 175 involved releases of fuel oil/lube oil in the engine room on board ships (the other 7 were determined to be outside the scope of this project), and 143 releases ignited and resulted in fires. Of the 143 fires caused by releases of fuel oil/lube oil, 9 fires are known to have resulted in fatalities and another 8 are known to have resulted in personnel injury.

Our investigation provided the following insights:

- Oil releases on board ships have occurred because of a variety of human-related and/or equipment-related causes. Although each incident is unique regarding the specific cause of failure, we identified six general categories of causes of

failure: (1) lack of adequate inspection or maintenance (10% of all releases), (2) personnel error during inspection or maintenance (25%), (3) personnel error and/or equipment failure during preparation for inspection/maintenance or restoration to service after inspection/maintenance (10%), (4) design, manufacturing, or installation deficiencies (20%), (5) unknown root cause (30%), and (6) external impact (5%). Obviously, improvements in human factors and management systems are essential for reducing the frequency of releases.

- Hot surface (particularly engine exhaust manifold/pipe, turbocharger casing, and steam line) was responsible for the ignition of about 93% of all fires, 93% of all fires with injury or fatality, and 86% of the fires with fatalities. Obviously, control measures to prevent oil sprays from reaching hot surfaces are essential for reducing the frequency of oil spray fires in engine rooms.

- The skid piping, tubing, or hose for diesel engines, turbochargers, or boilers are the most common sources of spray (almost 40% of all fires). These results are interesting because skid piping/tubing/hose is usually under the control of the manufacturer (i.e., the piping/tubing/hose that comes with an engine skid or pump skid), and it is generally not subject to regulations and standards that are in place for piping outside the engine/pump skid. Obviously, control measures to prevent oil sprays from skid piping/tubing/hose are essential for reducing the frequency of oil spray fires in engine rooms.

- Duplex strainers, filters, or coalescers are the most common sources of fatal spray fires (55%). In one case, a crew member damaged the O-ring of a strainer cover, resulting in a leak. In another case, a temporary change to a duplex strainer defeated an original safeguard (safety pin) provided by the manufacturer. This eventually led to an oil spray that ignited. In two other cases, the crew was having difficulties moving the three-way transfer valve to divert flow from one strainer chamber to the other chamber so that the strainer element could be cleaned or changed. In one instance, the crew member decided to loosen the mounting bolts of the packing retaining cover to facilitate movement of the valve. This was done excessively, resulting in an oil spray through the packing retaining cover. In the other instance, the crew member decided to kick the lever on the duplex strainer. He inadvertently hit a vent valve, which ruptured and released an oil spray. In both cases, while attempting to overcome an equipment malfunction (stuck transfer valve), crew members undertook unsafe actions that caused oil sprays and fires. Obviously, control measures to prevent oil sprays from duplex strainers/filters/coalescers are essential for reducing the frequency of fatal fires in engine rooms.

- Fuel oil systems account for about 70% of all oil fires while lube oil systems account for about 30%. However, when fires with fatality are considered, these contributions are 50% for fuel oil systems and 50% for lube oil systems. This indicates that while fuel oil fires occur more often (about twice as much) than lube oil fires, the fewer lube oil fires have caused as many fatal incidents as fuel oil. This suggests that the probability of a fatality given a lube oil fire is more than twice the probability of a fatality given a fuel oil fire. *Lube oil fires are less frequent than fuel oil fires, but they tend to be more fatal when they do occur.*

- Of all 57 incidents that documented the damage incurred by a spray fire, the vessel sank in 6 of the incidents, suffered constructive total loss in 9 of the incidents, and experienced an average damage of about $293,000 in the remaining 42 incidents.

- Of all 105 incidents that documented the impact of the spray fire on the propulsion and/or steering systems, vessels experienced loss of propulsion and/or steering in 70 incidents and were able to maintain these functions in 35 incidents. These are important statistics because loss of propulsion and/or steering can lead to other incidents such as grounding and collision. These numbers indicate that the probability of loss of propulsion and/or steering is about twice the probability of not losing these functions during spray fires in the engine room.

- It has been proposed that mist detectors can be strategically located in the engine room to indicate hazardous oil spray conditions (Reference 6). Our investigation revealed a different conclusion in this regard, at least for safety-related spray fires (i.e., fires that can result in personnel injury/fatality). Specifically, we observed that most safety-related oil spray fires in engine rooms occur during maintenance activities while the crew is in the engine room. These fires tend to ignite very quickly (in a matter of seconds in many cases). There is often insufficient time for crew evacuation, thereby resulting in personnel injury/fatality. Crews need no device or alarm to alert them to the presence of an oil spray in these cases. On the other hand, oil sprays that do not ignite quickly have a tendency to not ignite at all. *Thus, mist detectors would not have helped prevent or mitigate safety-related fuel oil/lube oil fires in the engine room.* The same conclusion also appears correct for non-safety-related spray fires (i.e., fires that cause equipment/vessel damage but do not result in personnel injury/fatality).

- There is no correlation between the number of spray fires and the ship's age, size, kind (oil tanker, fishing vessel, tug/tow, etc.) and nationality.

Our investigation resulted in several feasible, practical control measures to reduce risks associated with fuel oil/lube oil spray fires in engine rooms. Eighteen (18) recommendations for reducing the risks of spray fires are listed below. Section 4 of this report presents detailed discussions of each recommendation. The first 12 recommendations address specific changes to (1) existing fuel oil/lube oil equipment and systems and (2) management issues. These recommendations include improvements to inspections and maintenance, safe work practices, training, and emergency response. The next three recommendations address more significant changes to fuel oil/lube oil equipment in engine rooms. Because they may be too difficult to retrofit to existing ships, they are presented for new (or significantly modified) ships.

We also identified two areas that require additional research and development efforts; Recommendations 16 and 17 address these areas. Finally, our investigation of the causes of previous incidents revealed that much of the risk associated with fuel oil/lube oil spray fires stems from deficiencies in (or lack of) safety and reliability management systems. That is, the root cause of these incidents is generally the absence of, neglect of, or deficiencies in management systems; Recommendation 18 presents a general recommendation for ship operators to ensure that their management practices address all elements suggested in industry standards and guidelines.

Recommendations

1. Sheath, cover, or provide deflector shielding for fuel oil/lube oil piping, tubing, and hoses.

2. Sheath hot surfaces.

3. Provide deflector shielding between the fuel oil/lube oil strainer, filter, coalescer, or purifier and potential sources of ignition.

4. Duplex devices such as strainers, filters, or coalescers should not be opened when the fuel oil/lube oil system is in operation and pressurized.

5. Provide fine-water mist systems for local application on selected equipment areas in engine rooms, including diesel engine, turbocharger, and duplex strainer/filter/coalescer areas.

6. Ensure that all alterations (i.e., modifications that are not replacements-in-kind) to fuel oil/lube oil systems are unambiguously posted/logged.

7. Ensure that standard operating procedures (SOPs) are developed and implemented to operate duplex strainers/filters/coalescers in fuel oil/lube oil systems , operate (startup, shutdown, etc.) propulsion and auxiliary boilers, and fill fuel oil/lube oil tanks in machinery spaces.

8. Establish and implement safe work practices for fuel oil/lube oil.

9. Supplement periodic training of engine room personnel with a short video on the hazards of fuel oil/lube oil systems.

10. Ensure that the inspection and maintenance programs for fuel oil/lube oil equipment includes demonstration of the operation of three-way transfer valves in duplex strainers/filters/coalescers; periodic inspection and replacement of hoses, tubings, and fittings on diesel engines and turbochargers; and provisions for periodic inspection of devices that prevent sprays of oil.

11. Provide readily accessible emergency breathing apparatus to facilitate escape from engine rooms, and conduct periodic engine room fire and evacuation drills.

12. Ensure that hazard analyses are performed for systems containing pressurized fuel oil or lube oil.

13. Use diesel engines, fuel oil pumps, and lube oil pumps with integrated channels for fuel oil and/or lube oil (i.e., monolithic equipment housing).

14. When instrument signals (e.g., pressure indication) from fuel oil/lube oil systems are sent to gauge boards, pneumatic/electronic transducers should be used near the instrument tap to avoid lengthy runs of tubing or piping containing oil.

15. Duplex devices such as strainers, filters, or coalescers should not be opened when the fuel oil/lube oil system is in operation and pressurized.

16. Develop guidelines for fuel oil/lube oil fittings and nipples used in high-pressure marine applications.

17. Review existing design specifications and installation guidelines for insulation/lagging to ensure that these specifications and guidelines include provisions for preventing ignition.

18. Ship operators should ensure that their management practices are consistent with safety/environmental standards and guidelines.