Efficient Fire Detection Solutions for Ro-Ro Ships

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Abstract

Early detection is often considered as key to prevent loss of life and extensive cargo damage on ships. The FIRESAFE II study [1] evaluated risk control options related to fire detection in ro-ro spaces, as well as available and emerging fire detection technologies for use in open ro-ro spaces and on weather decks. A review of relevant regulations was performed as well as an evaluation of the expected efficiency of the identified detection technologies, considering detection time, sensitivity to weather conditions, loading conditions and deck configuration, as well as cost. Two selected new technologies were evaluated in fire tests onboard a commercial ro-ro passenger ship and both were found functional and suitable for the relevant ro-ro space environments. Cost-effectiveness assessments were performed for the tested systems as well as for other identified risk control options. Both of the selected systems were found cost-effective.

This paper presents results from the FIRESAFE II study as well as preliminary outcomes from the Horizon 2020 funded LASH FIRE project [2]. The ambition of LASH FIRE is to greatly enhance the fire safety of ro-ro ships through a holistic approach to the problem, including quicker, more reliable and more robust technical means for fire detection, confirmation, localization and assessment in all types of ro-ro spaces.

Keywords: Fire detection, ro-ro ships, fibre optic heat detection, video detection

Introduction

Several recent total losses of ro-ro ships (e.g. Norman Atlantic, Sorrento, Lisco Gloria, Und Adriyatik) have stressed the need for investigating more efficient fire detection solutions. One of the main issues is the fire safety of open ro-ro spaces and weather decks, where conventional detection systems are not normally installed or as effective as in closed ro-ro spaces. To address this hazard, a separate part of the FIRESAFE II [1] project had the objective to investigate the possibilities
and effectiveness of alternative fixed fire detection systems on open ro-ro decks and on weather decks of ro-ro passenger ships. FIRESAFE II as well as the first FIRESAFE study were launched and funded by the European Maritime Safety Agency (EMSA) to improve the fire safety of ro-ro passenger ships by cost-efficient safety measures reducing the risk of ro-ro space fires.

Following the FIRESAFE projects, the Horizon 2020 funded LASH FIRE project [2] started in 2019 and aims at improving the fire safety of ro-ro ships through several different approaches including ignition prevention, detection, extinguishment and containment.

One of the work packages in the LASH FIRE project is focused on developing and demonstrating new and improved detection methods for the use on all types of ro-ro decks, including weather decks as well as open and closed ro-ro spaces with their different characteristics and challenges for fire detection.

Weather decks are generally not equipped with any fire detection system since it is not required. Weather decks are, as it sounds, open to the sky, which means that there is no deck head to mount fire detectors above the deck. This gives challenges for conventional fire detection techniques that require a sensor to be located where it can come in direct contact with the heat or combustion products above a fire.

Open ro-ro spaces are either open in both ends or in one end and with at least 10 % openings along the sides, providing effective natural ventilation. These spaces hence have ventilation conditions varying with the ambient wind and the main challenge for open ro-ro spaces as well as weather decks concerns the potentially significant ventilation, which can delay and delocalize detection. The smoke and heat from a fire will follow the air flow and may not be detected until reaching a fire detector in a different part of the space or late in the fire scenario due to being significantly diluted. The smoke and heat may also be ventilated out of the ship without reaching any detector. There are also challenges regarding the potential fire scenario since the ventilation may cause a rapid fire development. A fire in open ro-ro spaces and on weather decks potentially also affects escape ways, access to live-saving appliances and air intakes to the engine room and emergency generator space.

Closed ro-ro spaces have mechanical ventilation and the movement of smoke and hot gases are more predictable. To maximize the loaded cargo on board, the available clearance between the top of the vehicles and the deckhead is relatively small. This limits the possibility to mount sensors high above the vehicles for a possible overview and the line of sight to a fire.
Safety measures related to fire detection in FIRESAFE II

The main objective of FIRESAFE II was to improve the fire safety of ro-ro passenger ships by cost-efficient safety measures reducing the risk of ro-ro space fires, with an aim to discuss specific proposals for rule making. In Part 1 of the study, the objective was to identify a range of risk control options (RCOs) for detection and decision, and to assess the ones most likely to be cost efficient.

Fault trees were developed focusing on the main hazards identified during a Hazard Identification (HazId) workshop. The trees were quantified to gain an understanding of the impacts on risks and to investigate in further detail the important causes of the accident scenarios identified. In order to consider the different types of ro-ro spaces, different trees were developed for each space and quantified by investigation of available failure data, fire simulations and expert judgement.

A range of Risk Control Measures (RCMs) were identified based on the hazards identified. Fire detection related measures presumed an existing fire and were all classified as mitigating, rather than preventive. The RCMs were ranked by experts with regard to risk reduction potential and estimated costs. Based on the ranking and on the high-risk areas needing control in the fault tree, the RCMs with the highest potential were:

- Combined smoke and heat detection;
- Fibre optic linear heat detection (for open and closed ro-ro spaces);
- Ban / closure of side (Portside & Starboard) openings (open ro-ro spaces);
- Increased frequency of fire patrols;
- CCTV covering all decks;
- Thermal imaging cameras on weather decks;
- Flame detection on weather decks;
- Better addressability;
- Detector drone or camera on rail; and
- Additional detection means in Alternatively Fuelled Vehicles areas.

Three of the above RCMs were selected as Risk Control Options (RCOs) for further quantitative cost-effectiveness analysis, based on their perceived cost-effectiveness, technology readiness level (TRL), and availability. The fibre optic linear heat detection and thermal imaging camera were not selected since these were assessed in Part 4 of the study. Of the selected RCOs, only combined smoke and heat detection was found cost-effective for some types of new ro-ro passenger ships but not for existing ships, as seen in Table 1, assuming a Gross Cost of Averting a Fatality (GCAF) of €7 M.
Table 1. RCOs cost-effectiveness assessment.

<table>
<thead>
<tr>
<th>RCO</th>
<th>New buildings</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Cargo</td>
<td>Standard</td>
</tr>
<tr>
<td>Combined heat &amp; smoke detection</td>
<td>Not cost-effective</td>
<td>Cost-effective</td>
<td>Cost-effective</td>
</tr>
<tr>
<td>Ban / closure of side openings (open ro-ro soaces)</td>
<td>Not applicable</td>
<td>Not cost-effective</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Increased frequency of fire patrols</td>
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<td>Not cost-effective</td>
</tr>
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<tr>
<th>Detection system</th>
<th>New buildings</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo RoPax</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard RoPax</td>
<td></td>
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<tr>
<td>Ferry RoPax</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined heat &amp; smoke detection</td>
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Part 2 and 3 of the FIRESAFE II study focused on extinguishment, containment and evacuation and is not part of the scope of this paper.

**Fire test results from FIRESAFE II**

The objective of Part 4 of the FIRESAFE II study was to investigate the possibilities and effectiveness of available and emerging fixed fire detection systems for open ro-ro spaces and weather decks. A review of relevant regulations was performed as well as an evaluation of the expected efficiency of the identified detection technologies, considering detection time, sensitivity to weather conditions, loading conditions and deck configuration, as well as cost. The evaluated technologies included fibre optic linear heat detection, aspirating smoke detection, gas detection, flame detection and video detection. For video detection there was three different subgroups considered: thermal imaging, analysis of flames (only) in the visual spectrum and analysis of smoke and flames in the visual spectrum.

A selection was made for further evaluation of two specific systems based on an extensive literature review and workshops among project partners, considering relevance and applicability for open ro-ro spaces.
and weather decks, including qualitative evaluation of the activation time and sensitivity to false alarms and faults, as well as evaluation of costs. While the cost of a conventional point smoke and heat detection system for open ro-ro spaces was estimated to € 55 000, the estimated total costs for evaluated technologies varied from € 50 000 to € 105 000. For the systems considered for weather decks, the costs varied from € 65 000 to € 150 000. The selected systems were a fibre optic linear heat detection system for the open ro-ro space and a thermal imaging camera system for the weather deck. Both selected systems were evaluated in fire tests onboard a commercial ro-ro passenger ship.

In the tests, an LPG burner was used to reproduce a cargo fire and several fire scenarios were evaluated to challenge both detection systems. On the weather deck, the thermal imaging camera detected a relatively small fire (80 kW) at a distance of about 50 meters. It was also capable of detecting a fire when the gas burner was fully obstructed (after about 3 minutes for a fire of 300 kW) or half obstructed (after half a minute for a fire of 80 kW). Even when heavy rain was simulated between the fire source and the thermal imaging camera, fire was detected (after 4 minutes for a fire of 400 kW), see Fig. 1.

![Thermal imaging camera](image.png)

**Fig. 1.** Position of thermal imaging camera with fire half-obstructed behind container and simulated heavy rain.

For the open ro-ro space, the fibre optic linear heat detection system showed capacities to detect a fire faster than a conventional point heat and smoke detection system. The improved performance was judged to be mainly attributed to the used detection criterion, based on a rate of temperature rise instead of a given peak temperature, as well as that the fire source did not produce much smoke. Furthermore, the new system also provided improved coverage and thus a shorter required traveling
distance of the hot gases, contributing to further shortened detection times. For the conventional system, the smoke sensor was still faster to detect the test fire compared to the heat sensor. Fig. 2 gives an overview of the installed fibre optic cable in relation to fire positions, existing point heat and smoke detectors and wind influence.

After the onboard fire tests, the false alarm rate of each system was evaluated by leaving the systems onboard for one month. The vessel did not record any fire or false alarms from the conventional heat and smoke detection system nor from the fibre optic linear heat detection system. The thermal imaging camera system recorded many alarms, but only during cargo loading and unloading, which was addressed and fixed by changing the sensitivity settings. The system allowed different settings to be used at dockside compared to when the vessel is at sea.

The tests were also complemented by simulations to make an assessment of the risk reduction potential of each system. Finally, based on test results and other data retrieved in the study, a cost-effectiveness assessment was performed for the two systems. Both systems were found cost-effective for most ships, both as retrofit and for new buildings, as shown in Table 2.

Table 2. Cost-effectiveness assessment of tested systems.

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</table>

| Detection system                  | Cargo RoPax   | Standard RoPax | Ferry RoPax |
|-----------------------------------|---------------|
|                                   |               |                |
| Fibre optic linear heat detection | Not cost-effective | Cost-effective | Cost-effective |
| Thermal Imaging Camera            | Cost-effective | Cost-effective | Cost-effective |
Fig. 2. Position of fibre optic cable in relation to fire positions, existing detectors and wind influence.
Continued evaluation of detection systems in LASH FIRE

In LASH FIRE, several different detection technologies are currently being evaluated and some will be tested, both in lab-scale setup and in realistic environments onboard a ro-ro ship. As the sensing technologies are sensitive to different fire characteristics, the fire sources will be varied with respect to the amount of smoke, heat and visible flame that is generated. A fire source that generates large amounts of heat, but low levels of smoke and visible flame is likely to be detected first by heat sensitive detectors. Fires with low heat release rates, little visible flames, but large quantities of smoke will most easily be detected by smoke sensitive detectors etc. An assessment of which types of fire signatures that are expected in ro-ro ships will be made. In addition, the smoke and heat movement under different ventilation conditions in open and closed ro-ro spaces will be simulated in order to predict the time to detection for different systems.

The different types of ro-ro spaces put different requirements on the detection systems. E.g. for weather decks, detector principles that rely on detection from a distance based on optical principles will be evaluated. The most relevant types are thermal imaging cameras and flame detectors sensitive to infrared and ultraviolet emitted light. For the use on weather decks, these principles have the main advantage that the sensors can be mounted at a distance from the heat and/or flame that they are detecting. On the other hand, they require a free line of sight from the sensor to the heat or flame that they are detecting. On a fully and tightly loaded weather deck this can be a challenge if the origin of the fire is concealed in-between vehicles, out of sight for the detectors as seen in Fig. 3.

Fig. 3. Fully loaded weather deck illustrating the tight conditions. Picture from DFDS.
The use of alternative sources of information are evaluated as well, both for fire detection as well as for localization and confirmation of fire. Drones or other types of moving sensor platforms can be used to place various types of sensors at points of interest. Depending on the sensors that are implemented, they can stream optical or thermal images or gas sensor data to the bridge where the decisions are made regarding what mitigating actions to initiate. Other sources of information can be sensors installed in the vehicles if the sensor data can be made available and monitored during the voyage. Any temperature increase in the parked vehicles could be considered as a warning to be followed up by a manual inspection or other suitable investigation. However, this information is currently not available from parked vehicles.

As the different types of ro-ro spaces have different requirements and conditions for the detection system, it will probably not be possible to find a single solution that is optimal for all decks. Integration of different detection systems and other useful sources of information into a single operator interface will also be developed within the LASH FIRE project.

**Final Remarks**

The evaluation and testing of the new fire detection technologies proved their usefulness on ships. The results from the FIRESAFE studies have now been reformulated into proposals for changes in maritime rules and guidelines. Rules are suggested to be changed both to facilitate use of alternative systems and to include requirements on fixed fire detection on weather decks. The International Maritime Organisation, IMO, is currently considering these proposals.

LASH FIRE will provide more information and knowledge to this subject and will further support the use of new and emerging fire detection technologies in the maritime industry. The project will continue for another two years and will include further fire tests, which will most probably be the subject for papers to future AUBE/SUPDET conferences.

**Acknowledgements**

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**References**