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Ship integration requirements

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Abstract

This report presents the ship integration requirements addressed to all the developments within the LASHFIRE project. To ensure a good quality starting point for the addressed developments, it is crucial that ship designers and operators are involved in the development process. Thus, specific input has been prepared, adjusted to each development, considering the design, production, operational and environmental aspects as well as applicable rules and regulations. Further, all types of ro-ro ships and all types of ro-ro spaces have been considered where appropriate. Finally, expectations and proposal for the developments have been given. This ensured a good starting point for the development teams, making a clear picture of the end user requirements.

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Content

1 Executive summary 6
2 List of symbols and abbreviations 7
3 Definitions 9
4 Introduction 11
5 Manual screening of cargo hazards and effective fire patrols - Action 6-A 12
6 Quick manual fire confirmation, localization and assessment - Action 6-B 19
7 Efficient first response - Action 6-C 26
8 Effective and efficient manual firefighting- Action 6-D 37
9 Improved bridge alarm panel design - Action 7-A 47
10 Efficient extinguishing system activation and inherently safe design - Action 7-B 65
11 Firefighting resource management centre - Action 7-C 80
12 Automatic screening and management of cargo hazards- Action 8-A 97
13 Guidelines and solutions for safe electrical connections - Action 8-B 105
14 Fire requirements for new deck materials - Action 8-C 115
15 Means for detection on weather deck - Action 9-A 126
16 New means for fire detection in closed and open ro-ro spaces - Action 9-B 131
17 Means for automatic fire confirmation, localization and assessment - Action 9-C 150
18 Local application fire-extinguishing systems - Action 10-A 155
19 Weather deck fixed fire-extinguishing systems - Action 10-B 168
20 Updated performance of alternative fixed fire-fighting systems - Action10-C 179
21 Division of ro-ro spaces - Action 11-A 193
22 Ensuring safe evacuation – Action 11-B 203
23 Safe design with ro-ro space openings - Action 11-C 210
24 Ro-ro space ventilation and smoke extraction – Action 11-D 216
25 Conclusion 228
26 References 229
27 Indexes 233
ANNEX A 237
ANNEX B 257
ANNEX C 270
ANNEX D 276
ANNEX E 282
ANNEX F 286

ANNEX G 292
ANNEX H 300
ANNEX I 333
ANNEX J 341
ANNEX K 353

1 Executive summary

1.1 Problem definition

The LASH FIRE project aims to develop and demonstrate operational and design solutions which strengthen the fire protection of ro-ro ships in all stages of a fire. Twenty specific challenges, also called Actions, have been identified, which will be addressed by new solutions developed and demonstrated with regards to performance and ship integration feasibility. Real ship application cases are important, as a starting point for the development, and later for the evaluation and demonstration of ship integration feasibility as well as for cost quantification. Therefore, it is crucial that ship designers and operators are involved in the development process.

The main challenges were to address all the application areas, targeted by developed solutions, and providing a clear picture of the end user requirements.

1.2 Technical approach

To address the described problems and challenges above, specific input was provided to the development teams, adjusted to each development separately, considering the design, production, operational and environmental aspects as well as applicable rules and regulations. Further, all types of ro-ro ships and all types of ro-ro spaces were considered where appropriate. Finally, expectations and proposals for the developments were given.

1.3 Results and achievements

This report presents the ship integration requirements addressed to all the developments within the LASHFIRE project. Together with the selected generic ships (ref. LASH FIRE Deliverable D05.1), this ensured a good starting point for the development teams, making a clear picture of the end user requirements, and definition of the scope and required functions for the solutions to be developed.

1.4 Contribution to LASH FIRE objectives

One of the main LASH FIRE objectives (Objective 2) is addressed by the ship integration work package (WP05):

> *LASH FIRE will evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces.*

This report will further set the basis, not only for the development, but also for evaluation and demonstration of integration feasibility for all the developed solutions within the LASH FIRE project and beyond.

1.5 Exploitation and implementation

The results will be used within LASH FIRE as input for the development of technical and operational solutions, and they will be further used to evaluate integration, lifecycle cost assessment and facilitate for demonstration.

The report can be used by external parties as it provides a comprehensive description of current technical and operational state of the art and challenges related to fires originating in ro-ro spaces. Further, it provides information on the expected or desired improvements and future developments.

This information can be useful by any stakeholder in the maritime industry.

2 List of symbols and abbreviations

AB	Able Sea man
ADR	Accord européen relatif au transport international des marchandises Dangereuses par Route (European Agreement Concerning the International Carriage of Dangerous Goods by Road)
AIS	Automatic Identification System; Satellite transmitted positions of vessels.
APV	Alternative Powered Vehicle
CAFS	Compressed air foam system
CCR	Cargo control room
CCTV	Closed-Circuit Television
CLIA	Cruise Lines International Association
DECT	Digital Enhanced Cordless Telephone
DG	Dangerous cargo
ECDIS	Electronic Chart Display and Information System; Electronic map and navigation tool
ECR	Engine Control Room
FRMC	Firefighting Resource Management Centre
FSS	IMO International Code for Fire Safety Systems
FTP	International Code for the Application of Fire Test Procedures
FWBLAFFS	Fixed Water-Based Local Application Fire-Fighting Systems
IACS	International Association of Classification Societies
IAMCS	Integrated Alarm Monitoring Control System – equipment
ICE	Internal Combustion Engine
IEC	International Electrotechnical Commission
IMDG	The International Maritime Dangerous Goods code
IMO	International Maritime Organization
ISM	International Safety Management
ISPS	International Ship and Port Facility Security Code
LLL	Low Location Lighting
MES	Marine Evacuation System
MFAG	Medical First Aid Guide for Use in Accidents Involving Dangerous Goods

MSC	Maritime Safety Committee
MVZ	Main Vertical Zone
OOW	Officer Of the Watch
SCS	Safety control station, normally located on the bridge
SOLAS	International Convention for the Safety Of Life At Sea
SRtP	Safe Return to Port
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
TUGMASTER	The small vehicle that drives the trailers on/off board
UHF	Ultra Hight Frequency; Short wave radio, shorter reach than VHF
VGM	Verified Gross Mass
VHF	Very High Frequency; Short wave radio

3 Definitions

Main author of the chapter: Blandine Vicard, BV

This section provides the definitions of key terms used in the Report.

3.1 Ro-ro space, vehicle space and special category space

As per SOLAS II-2/3:

- "*Vehicle spaces are cargo spaces intended for carriage of motor vehicles with fuel in their tanks for their own propulsion.*"
- *"Ro-ro spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction."*[1]
- *"Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m."*
  Special category spaces are ro-ro spaces to which passengers have access, possibly during the voyage. Special category spaces are the most frequent type of closed ro-ro spaces on ro-ro passenger ships.
  It is to be noted that open ro-ro spaces are not considered as special category spaces.

3.2 Closed, open and weather deck

As per SOLAS II-2/3:

- A "*weather deck is a deck which is completely exposed to the weather from above and from at least two sides.*"
  IACS UI SC 86 additionally details that: "For the purposes of Reg. II-2/19 a ro-ro space fully open above and with full openings in both ends may be treated as a weather deck."
  For practical purposes, drencher fire-extinguishing system cannot be fitted on weather decks due to the absence of deckhead. This criterion is often used for a practical definition of weather decks.
- An open vehicle or ro-ro space is "*either open at both ends or [has] an opening at one end and [is] provided with adequate natural ventilation effective over [its] entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides.*"
- A closed vehicle or ro-ro space is any vehicle or ro-ro space which is neither open nor a weather deck.

As a reference criterion, it can be considered that a vehicle space that needs mechanical ventilation is a closed vehicle space.

[1] In other words, ro-ro spaces are vehicle spaces into which vehicles can be driven. It is to be noted however that, for the purpose of the application of SOLAS II-2/19, the following interpretation can be found in MSC.1/Circ.1120 and IACS UI SC 85: "Ro-ro spaces include special category spaces and vehicle spaces".

3.3 Main Vertical Zone

For practical purposes, a main vertical zone (MVZ) is a slice of the ship which is insulated from the rest of the ship and in which the fire safety systems need to be somehow segregated from the other MVZ. MVZ are defined on passenger ships only.

3.4 Central control station and safety centre

The two terms were developed by IMO in parallel, separately and at different times.

The definition of the “central control station” and its control and indicator functions is provided by SOLAS II-2 Reg.3.9 [5]. The central control station can either be part of the navigation bridge or be located in a separate space. For practical purpose, the central control station is very often the navigation bridge.

The “safety centre” is a new requirement applicable to passenger ships constructed on or after 1 July 2010. Its control and monitor functions are provided by SOLAS II-2 Reg.23.6 [5]. More control and monitor functions are required for safety centre than for central control station. Moreover, the safety centre shall either be a part of the navigation bridge or be located in a separate space adjacent to and having direct access to the navigation bridge. For practical purpose, when there is a safety centre, it will also act as the central control station.

4 Introduction

Main author of the chapter: Vito Radolovic, FLOW

One of the main LASH FIRE objectives (Objective 2) is to evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces. Thus, a good quality input shall be given to the development teams in the very beginning of the development process to achieve this goal.

The development teams are grouped within six Development and Demonstration Work Packages (D&D WPs) that will address a total of twenty challenges, also called actions, in all stages of fire course originating in ro-ro spaces (Figure 1).

WP06	**Effective Manual Operations**
6-A	Manual screening of cargo fire hazards and effective fire patrols
6-B	Quick manual fire confirmation and localization
6-C	Efficient first response
6-D	Effective and efficient manual firefighting
WP07	**Inherently Safe Design**
7-A	Improved fire detection system interface design
7-B	Efficient extinguishing system activation and inherently safe design
7-C	Firefighting resource management centre
WP08	**Ignition Prevention**
8-A	Automatic screening and management of cargo fire hazards
8-B	Guidelines and solutions for safe electrical connections
8-C	Fire requirements for new ro-ro space materials
WP09	**Detection**
9-A	Detection on weather deck
9-B	Detection in closed and open ro-ro spaces
9-C	Technologies for visual fire confirmation and localization
WP10	**Extinguishment**
10-A	Local application fire-extinguishing systems
10-B	Weather deck fixed fire-extinguishing systems
10-C	Updated performance of alternative fixed fire-fighting systems
WP11	**Containment**
11-A	Division of ro-ro spaces
11-B	Ensuring safe evacuation
11-C	Safe design with ro-ro space openings
11-D	Ro-ro space ventilation and smoke extraction

Figure 1. LASH FIRE 20 challenges (or actions).

This report presents the ship integration requirements addressed to all the developments, specifically to each challenge (or action) within the LASHFIRE project. To ensure a good quality starting point for the addressed developments, it is crucial that ship designers and operators are involved in the development process. Thus, specific input has been prepared, adjusted to each development, considering the design, production, operational and environmental aspects as well as applicable rules and regulations. Further, all types of ro-ro ships and all types of ro-ro spaces have been considered where appropriate. Finally, expectations and proposals for the developments have been given. This ensured a good starting point for the development teams, thus making a clear picture of the end user requirements.

5 Manual screening of cargo hazards and effective fire patrols - Action 6-A

Main author of the chapter: Martin Carlsson, STL

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 6-A i.e. Manual screening of cargo hazards and effective fire patrols.

5.1 Short Description of the addressed Action

Action 6-A objective is to develop a methodology that allows the manual screening of cargo and the implementation of effective fire patrol procedures and routines through:

- Definitions of conditions for manual screening of cargo fire hazards and effective fire patrols
- Development and demonstration of efficient manual screening routines of cargo fire hazards
- Development and demonstration of effective fire patrol procedures and equipment

5.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the rules and regulation requirements applicable in ro-ro spaces for the action 6-A.

5.2.1 Applicable regulations

The present review is based on the regulations listed in Table 1 below.

Table 1: List of documents used for the review of regulations for Action 6-A

IMO Documents	SOLAS 74 – International Convention for the Safety Of Life At Sea, as amended
	IMDG Code
	ISM Code – International management code for the safe operation of ships and for pollution prevention
	ISPS Code - International Code For The Security Of Ships And Of Port Facilities
	IMO MSC.1/Circ.1615 - Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue Book, 2019
Flag Administration Rules	SOR/2017-14 - Vessel Fire Safety regulations published by the Minister of Justice of Canada, Current to March 19, 2020
	UK MSIS 12 - Statutory guidance for fire protection arrangements, dated June 2014

5.2.2 Requirements

5.2.2.1 Fire patrols

SOLAS requires efficient fire patrols to be organized onboard passenger ships carrying more than 36 passengers. The members of the fire patrol are to be:

- “trained to be familiar with the arrangements of the ship as well as the location and operation of any equipment he may be called upon to use.”
- “provided with a two-way portable radiotelephone apparatus.”

[SOLAS II-2/7.8]

Some Flag Administrations, such as Transport Canada, additionally require that the fire patrols on passenger ships need to be carried out every hour and should cover the entire ship.

[Transport Canada Vessel Fire Safety regulations, 117(2)]

Furthermore, the ISM Code requires that any company operating a ship sets up a safety management system with identified persons in charge of the relevant duties and procedure to report incidents, prepare for and respond to emergency situations. The fire patrols are to be included in this safety management system.

In addition, efficient fire patrols are specifically required in any special category space (i.e. also on passenger ships carrying not more than 36 passengers).

[SOLAS II-2/20.4.3.1]

UK Flag Administration clarifies that “inspection of the vehicle decks [is to] be carried out immediately after loading and prior to discharge. The patrol system should be maintained when ships in service are in port. Every part of the ship accessible to the fire patrol should be visited regularly. The value of openings to holds, store and baggage rooms should not be overlooked, as fire can be detected by sight or smell.”

[UK MSIS 12 Ch 10 §4.1.2]

More detailed recommendations for fire patrols in ro-ro spaces can be found in the “Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships” recently issued by IMO, including minimum check points during the fire patrol:

- leakages from the vehicles;
- conditions of electrical connections and ship's power supply cables to vehicles; and
- common cargo fire hazards.

[MSC.1/Circ.1615 §1.7.1]

And the recommendation that “portable thermal imaging devices be used for screening during fire rounds and upon suspicion to detect hot areas and overheated electrical equipment.”

[MSC.1/Circ.1615 §1.7.2]

5.2.2.2 Cargo screening

No explicit requirement for systematic cargo screening – with respect to fire safety – has been identified in the international regulations, except that vehicles entering vehicle, ro-ro or special category spaces are assumed to be inspected for leakage.

When they are carried in a vehicle, special category or ro-ro space, vehicles do not fall in the scope of IMO IMDG Code. However, it can be outlined that IMDG Code mentions that there should be "no signs of leakage from the battery, engine, fuel cell, compressed gas cylinder or accumulator, or fuel tank when applicable."

[IMDG Code Ch 3.3 SP 961. This recommendation is provided as a condition for vehicles carried in vehicles, special category or ro-ro spaces for not being subject to IMDG Code]

As a side note, it is outlined that the Ship Security Assessment required by IMO ISPS Code for ship security purposes normally includes cargo screening, including dangerous cargo and with a focus on unaccompanied luggage, as outlined by IACS Rec.81.

Finally, IMO recently issued "Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships" recommends that video monitoring of the ro-ro spaces, which may make cargo monitoring and screening easier, although this is not the primary objective of this measure (It is rather intended for fire confirmation).

[MSC.1/Circ.1615 §2.2.2]

5.3 Operational aspects

In this chapter, the operational aspects are given, resulting from interviews with numerous crew members of multiple Stena ro-pax vessels, various Stena office staff and authors experience.

5.3.1 Screening of cargo/vehicles at terminal

The following conditions shall be considered at screening of cargo at port terminals:

- Screening of incoming cargo management at terminals. Current practice at Stena's terminals considers individual management on each terminal
- Staff availability limits the onsite possibilities
- Late arrival of cargo reduces the available time for inspections
- Risk base selection system for resources' management
- Cargo/Task management systems. For example, the Stena's *rePORT* system has the possibility for the task status check assignment at terminal and onboard. Tasks may be based on a known or gate-scanned vehicle data. Further, cargo unit onboard position can be provided by the system
- Instructions to the truck drivers.
- Inspections instructions. Currently available in form of physical booklets and/or web-based Smartphone Applications

More detailed information on Stena's Instructions and task management system is presented in ANNEX A.

5.3.2 Screening of cargo at time of loading

During the cargo loading operations on board the ship, deck officers and crew members have to be focused on the loading process, cargo stowage and traffic management at the same time as cargo screening operation. Available time to execute cautious checking of vehicles during loading on board (usually at rampway, entrance into the ship) is very limited, where only obvious conditions are noticed. Depending on the port practice, loading and lashing of cargo can be carried out by stevedores, and not by the crew.

Regarding the refrigerated cargo units (reefer units), the general policy is that the responsibility is on the forwarders. All operations with such cargo should normally be reduced to a minimum on behalf of ship operator's side, to avoid the responsibility such as temperature issues and eventual cargo loss.

Malfunctions like fuel leakage and suspicious noise are generally noticed immediately at cargo screening where immediate actions are taken.

5.3.3 Fire patrols

Generaly, the fire patrol procedure can be summarised as follows:

a. To detect fires or related risk situations and other events endangering ship safety
b. inform OOW on situation if detected
c. Act as first response on site

The following conditions shall be considered for the fire patrol procedures and routines on board:

- Purpose definition
- Minimum watchkeeping manning;
  - Two (2) ABs for ro-pax vessels carrying more than 12 passengers; and
  - One (1) AB for ro-ro cargo vessels carrying 12 or less passengers
- Fire patrols only required for passenger ships carrying more than 36 passengers
- Special conditions may be issued for first and last fire patrol due to preparations for arrival or departure. Timing of fire rounds at departure and arrivals may be influenced by navigational or other operational conditions;
- Fire patrol to be properly trained with first response fire equipment, combined duties as fire crew to be considered;
- Fire patrol to be properly informed and trained with their procedures and restrictions in term of use of fire suppression measures such as drencher, fire hose, or portable extinguisher,
- Maximum duration of one fire patrol round; preferably maximum 45 min, in order to fit into one-hour watch schedule and allow for additional duties and a short break before the next round;
- Areas to be patrolled; Not only cargo space, but also crew accommodation, service areas, public areas and outside deck areas;
- Clear and explicit instructions; appropriate for temporary staff efficient fire patrol
- Obstructions: Visibility obstructed by high cargo, limited accessibility to all vehicles due to tight parking;
- Other fire threats; Awareness of fire threats, other than cargo, such as vessel hydraulic system leaks, electric failures, etc.;
- Fire patrol to alert of damaged/disabled fire safety equipment;
- Fire patrol to alert of suspicious behaviour of passengers/crew;
- Increased risk of fire up to 1,5h after departure and just before arrival, according to statistical data;
- Late arrival of vehicles: Increased risk and limited time for proactive scanning;
- Check point arrangement: Check points to be selected wisely to support good coverage of patrol path;
- Fire patrol to concentrate on weak spots in fixed detection systems;
- Procedure deviations: In some cases instructions cannot be strictly followed, for example during loading operations;

- Fire screening on ro-ro vessels where no fire patrols are required;
- Fire patrol equipment; current equipment considers IR camera, radio, checkpoint reader and flashlight;
- Physical fitness of fire patrol crew must be taken into consideration.

5.3.4 Current practise at Ports and Stena's vessels

5.3.4.1 Ro-pax vessels

This section gives an overview of the current practice on Stena ro-pax vessels.

Refrigerated cargo units

Procedures related to the operation with refrigerated cargo units are listed below:

- Reefer cables are pulled to the connection point on reefer unit by the crew, where the actual connection to the unit is, in general, done by the driver. In some cases, exceptionally, the connection is done by the electrician (Gothenburg- Kiel route);
- The disconnection of the cables is done by the crew to avoid damages of the cables as in practice it is shown that the disconnection procedure is not performed adequately by the drivers (the drivers very often forget to disconnect the cables);
- Cables are disconnected and stowed on on cable reels or coiled manually before arrival.

Fire patrols

Generally, the duration of one fire patrol round is up to one hour, where no fire patrols are organised during the day time (0800-1600). Walking speed varies significantly, as well as focus on detecting dangers. Fire patrol schedule examples as follows:

- Departure 1600 arrival 1915, fire patrols 1700 & 1800;
- Departure 2015 arrival 2350, fire patrols 2100, 2200 and 2300;
- Total fire patrol duration of 25-35 minutes, including 5-7 minutes inspection of the cargo decks.

There are no written instruction of procedure during the fire patrol. Instructions are verbally transferred between the crew at the introduction. A list of all check point supports the fire patrol if needed. Most common practical procedures at the fire patrol are listed below:

- Fuel leaking is the most common observation during the fire patrol. In such cases, a photo is taken, absorbent applied and OOW informed.
- If it is found out that the reefer unit is running on diesel in a closed cargo space, the driver is informed and the unit is shut down
- If it is not possible to follow the planned route due to tight stowage of cargo units, fire patrol may choose to take another one.

Observations related to the fire patrol equipment ale listed below:

- Internal communication: full "radio" coverage in all spots of fire round is required;
- Heat camera is carried by the fire patrol crew in some cases;
- During the patrol, protective trousers and shoes are necessary, but long sleeve protective sweater is not worn in most of the cases.

5.3.4.2 ro-pax vessels in the North Sea operation

This section aims at giving an overview of the current practice on three large and one standard Stena ro-pax vessels operating in the North Sea area. Most common practical procedures and observations are listed below:

- Patrols commenced as soon as "At sea", day and night
- Fire patrol duration of 30 minutes
- The registration of the fire patrol check points is displayed on bridge in real time, on one of the considered vessels.
- IR camera is part of the standard equipment
- Good radio coverage in general, recent upgrades in the equipment. Blind spots in the communication known.
- Fire patrol Instructions booklets available
- General opinion is that fire patrol motivation is good
- Reefer units run on diesel in the open cargo space and weather decks
- Reefer units are connected by the driver on closed decks, disconnected by crew. The crew is "supporting" at time of connection on one of the considered vessels.

5.3.4.3 Port operations at Scandinavian ports

This section aims at giving an overview of the current practice during the Stena ro-pax vessels operation at Scandinavian ports. Most common practical procedures and observations are listed below:

- 4 tug master available during manoeuvring;
- 5 port staff serve daily from 10 to 100 loose trailers, with an average of 50/day in one direction. From 1 to 2 loose trailers are reefers. Total 3 departures per day;
- Average number of trucks with a driver is 160/day of which 15 are reefers, however, there are very large seasonal/daily variations;
- Loose trailer cut-off 90 min before departure, driven vehicles 60 min to keep slot, gate closes 15 min before departure;
- as less as possible manual checking is the main objective;
- Manual checking considerations: unit dimension LxBxH check, outer damages check, DG marking check with respect to the information given at booking. If irregularities are observed, more detailed inspection is performed;
- Refrigeration units are not checked at the terminal. For plugged in or diesel operation while parked in terminal, the responsibility is on the driver;
- Refrigeration unit electric connections are checked onboard by the crew. If rejected by the check onboard, the units are returned ashore, which is the case few times per year . In some cases when stowed in the closed cargo space and electric system fails, refrigeration units are powered by diesel and run intermittently 1h by the fire patrol);
- Refrigeration units are plugged in by the crew, if onboard;
- Reefer units are generally (90% on the considered ports/ships) equipped with remote monitoring, including temperature, position and failure codes. Data is sent to the forwarder, who eventually contacts Stena if required. (Not working outside 4G network?);
- Cargo temperature is checked onboard only if agreed between Stena and the forwarder. If temperature is found out of the margins, Stena informs the forwarder. The crew never operates with the reefer unit;

- No information in booking system on AFV vehicles, no separate routines on arrival;

5.3.4.4 Port operations at North Sea ports

This section aims at giving an overview of the current practice during the Stena ro-pax vessels operation at North sea ports. Most common practical procedures and observations are listed below:

- All cargo handling onboard is performed by the stevedores;
- Instructions for manual cargo screening related to the fire risk are not available;
- Drivers are instructed to turn of heaters;
- No special treatment for electric powered vehicles;
- Waste transport marked with letter “A”;
- If fuel leakage and/or suspicious noise are observed, immediate action is taken
- Large number of cargo units at terminal, including last minute arrivals;
- Automatic screening would improve the cargo management. Equipment is already installed on site but still not yet in function;
- Manual and automatic screening activities on incoming vehicles are focused on vehicle damages and stowaways. Fire risk assessment is currently not performed.

5.4 Proposal for development and restrictions

This section gives the proposals and restrictions for developments compared to the current practice on the Stena ro-pax vessels operation, listed below:

- Shore staff training on fire hazards and consequences
- Continuous attention by frequent information exchange
- Specific cargo information available to shore staff
- Selective screening to increase hit-rate and limit required resources
- Possibility to check relevant indicators for fire hazard
- Inspection selection criteria instructions; for example, inspection checklist
- Reefer unit status available
- Alternative powered vehicles identification properly marked on the vehicle
- Cargo operation instructions to the driver
- Automatic screening output to be used as input to additional manual screening activities, if required

6 Quick manual fire confirmation, localization and assessment - Action 6-B

Main author of the chapter: Martin Carlsson, STL

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 6-B i.e. Quick manual fire confirmation, localization and assessment .

6.1 Short Description of the addressed Action

Action 6-B objective is to set a standard for quick manual fire confirmation, localization and assessment, through:

- Definition of conditions for manual fire confirmation and localization
- Development and demonstration of fire confirmation and localization
- Means of communication for fire confirmation

6.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 6-B.

6.2.1 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

Table 2: List of documents used for the review of regulations for Action 6-B

IMO Documents	SOLAS Convention, as amended
	ISM Code – International management code for the safe operation of ships and for pollution prevention
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
Flag Administration Rules	SOR/2017-14 - Vessel Fire Safety regulations published by the Minister of Justice of Canada, Current to March 19, 2020
	UK MSIS 12 - Statutory guidance for fire protection arrangements, dated June 2014

6.2.2 Requirements

6.2.2.1 General

International rules and regulation contain very limited requirements regarding "manual fire confirmation, localization and assessment" since this is a very operational matter. Two kinds of provisions can however be found:

- Provisions for on-board systems aimed to ensuring or easing fire confirmation:
  - Manually operated call points;
  - Organization of the fixed fire alarm and fire detection system, centralization of alarms;
  - Video monitoring; and
- Requirements for crew organization and readiness, including fire patrols

6.2.2.2 Manually operated call points (MOCP)

Manually operated call points are required throughout the ship and especially within special category spaces. Manually operated call points are not required in other ro-ro or vehicle spaces because it is not expected that passengers or crew members (other than the fire patrol who are equipped with radiotelephones) will access to those spaces.

Manually operated call points are required to be located close to the exits of the spaces, so that somebody who detects a fire can activate it while escaping.

[SOLAS II-2/7.7 and II-2/20.4.3.7]

Manually operated call points belong to the fixed fire alarm and fire detection system, which has to comply with the requirements of FSS Code Ch 9. Alarms from manually operated call points are led to the fire detection control panel.

6.2.2.3 Centralization of fire alarms

On passenger ships, all the fire alarms and controls for the safety systems are to be centralized in the safety centre.

[SOLAS II-2/23]

Note: The requirement for the safety centre is applicable to ships built after 01/07/2010. Prior to this date, there was already a requirement on passenger ships carrying more than 36 passengers that all fire alarms be gathered in a central control station, which is to be manned continuously.

[SOLAS II-2/7.9.3]

6.2.2.4 Video monitoring

IMO recently issued "Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships" recommends that video monitoring of the ro-ro spaces, in order to ease fire confirmation.

[MSC.1/Circ.1615 §2.2.2]

6.2.2.5 Crew organization and readiness

IMO ISM Code requires that any company operating a ship sets up a safety management system with identified persons in charge of the relevant duties and procedure to report incidents, prepare for and respond to emergency situations.

[IMO ISM Code]

For fire-related emergency situations, the following measures and documentation, required by SOLAS II-2, are to be included in this safety management system:

- Fire patrols, as detailed in [6.2.2.6] below
- Crew organization for fire-extinguishing

[SOLAS II-2/15.2.1.3]

- Instructions for crew members regarding fire safety on-board and their duty in case of a fire emergency

[SOLAS II-2/15.2.1 & 15.2.2]

- Requirements for on-board training are focused on fire-fighting (rather than fire detection). However, the training manual is explicitly to include “general instructions […] procedures for notification of a fire and use of manually operated call points” and “meanings of the ship's alarms”

[SOLAS II-2/15.2.2 & 15.2.3]

- A fire safety operational booklet is required on-board each ship and is to include “the necessary information and instructions for the safe operation of the ship and cargo handling operations in relation to fire safety. The booklet shall include information concerning the crew's responsibilities for the general fire safety of the ship while loading and discharging cargo and while under way”

[SOLAS II-2/16.2]

- Passenger ships’ crews are required to be so organized “as to ensure that any initial fire alarm is immediately received by a responsible member of the crew”

[SOLAS II-2/7.9.1]

6.2.2.6 Fire patrols

SOLAS requires efficient fire patrols to be organized on-board passenger ships carrying more than 36 passenger. The members of the fire patrol are to be:

- “trained to be familiar with the arrangements of the ship as well as the location and operation of any equipment he may be called upon to use.”
- “provided with a two-way portable radiotelephone apparatus.”

[SOLAS II-2/7.8]

Some Flag Administrations, such as Transport Canada, additionally require that the fire patrols on passenger ships need to be carried out every hour and should cover the entire ship.

[Transport Canada Vessel Fire Safety regulations, 117(2)]

The fire patrols are to be included in the safety management system required by the ISM Code.

In addition, efficient fire patrols are specifically required in any special category space (i.e. also on passenger ships carrying not more than 36 passengers).

[SOLAS II-2/20.4.3.1]

UK Flag Administration clarifies that “inspection of the vehicle decks [is to] be carried out immediately after loading and prior to discharge. The patrol system should be maintained when ships in service are in port. Every part of the ship accessible to the fire patrol should be visited regularly. The value of openings to holds, store and baggage rooms should not be overlooked, as fire can be detected by sight or smell."

[UK MSIS 12 Ch 10 §4.1.2]

More detailed recommendations for fire patrols in ro-ro spaces can be found in the "Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships" recently issued by IMO, including minimum check points during the fire patrol:

- leakages from the vehicles;
- conditions of electrical connections and ship's power supply cables to vehicles; and
- common cargo fire hazards.

[MSC.1/Circ.1615 §1.7.1]

And the recommendation that "portable thermal imaging devices be used for screening during fire rounds and upon suspicion to detect hot areas and overheated electrical equipment."

[MSC.1/Circ.1615 §1.7.2]

6.2.3 Other regulations

The below regulations are also outlined as they are understood not to be directly related to the present topic but may be of interest:

- IMO A.1021(26), IMO 2009 Code on alerts and indicators includes requirements about the type of alarms with a view to ensure easy identification of the issue triggering the alarm; and
- IMO MSC.1/Circ.1615 includes requirements intended to facilitate proper identification of the location of the fire in the ro-ro space, especially zoning coherence between fire-fighting and fire detection system.

6.3 Operational aspects

In this chapter, the operational aspects are given, resulting from interviews with numerous crew members of multiple Stena ro-pax vessels, various Stena office staff and authors experience.

6.3.1 General

Fire patrol must feel confident to perform duties in a good way. This includes the availability and reliability of adequate equipment, reliability of the bridge team, familiarization of all critical spaces on the vessel and awareness of possible scenarios that may be encountered.

Safe and quick access to spaces is crucial. Thus, free passageways shall be maintained as much as possible and the best entry point shall be used for accessing spaces. Further, space accessibility shall be known (locked doors, etc.) at all time and impact on the ventilation/fire conditions when accessing to the spaces.

At the fire patrol inside cargo spaces, reduced visibility (due to the cargo unit size) and tight stowage of cargo units have considerable impact on the fire suppression success rate.

It can be noted that procedures on the localization/confirmation of fire are in most cases very concise, see ANNEX B.

6.3.2 Visual localization

Size of numbers and letters of the drencher zone and frame markings should be sufficient for easy reading from long distance and all realistic locations. This is not the case on all ships, where various markings can be found.

For the drencher zones marking, all hoistable/movable car deck configurations shall be considered.

In a stressed situation it may be a challenge to determine the exact position on the ship (not only the position on the deck, but even the deck number).

Further, the information accuracy can be improved by fixed systems, such as addressable detectors, drencher zones and CCTV.

For examples drencher zones, frame numbers and decks markings, see ANNEX B.

6.3.3 Fire patrol equipment

Fire patrol equipment may consist of:

- UHF radio
- DEC telephone
- Portable IR camera
- Flashlight
- Check point scanner
- Set of keys/key cards/pin-codes for locked spaces inspection

No special fire outfit is required for fire patrol members other than their normal working outfit, even in cases that non-AB crew members are sent to the location of the indicated fire. Communication

A common problem on ro-pax vessels are blind spots in a radio communication. It is essential that a fire patrol can always be in direct contact with the bridge and at all control locations onboard. If this is not possible, time is spent on moving into the good radio coverage area, leading to a loss of real time information exchange when the uncertainties may arise.

Repeaters are in many cases installed, but there is still poor coverage on some vessels. The coverage can be improved by using additional systems such as DEC Telephone system or fixed emergency phone system, thus increasing the equipment complexity.

Predictability of messages is important, especially in cases of poor sound quality, to avoid ambiguity.

Further, concise and clear information transfer is important for the decision making.

Language issue should be duly considered in a multi-native language crew. The conversation should be kept in a crew native language, if possible. In cases of multi-language crew, English language must be used. The communication should be loud and clear and excessive talking should be avoided. Use of “Simplified Technical English” as few words as possible.

Standardized phrases examples are listed below:

“Deck 3 Port side, drencher zone 24, Fire in reefer confirmed”
“Fire patrol, report status”
“Vehicle on fire identity WGS 133, open flames from left side mid trailer”
“Fire party 2 entering dk 2 starboard side”
“Weather deck aft, starboard side, dense smoke confirmed”
“Manual hose now engaged from aft”

"Activate drencher zone 14 dk 4, repeat activate drencher zone 14 dk 4"
"Need medical assistance, NN has breathing problems"

6.3.4 Training and procedures, situation awareness before entry

Knowledge gained during training of different fire scenarios definitely improves the quality and speed of communication in a real fire case. Fire patrol should be aware of the cargo type, stowage, location, etc. before or while proceeding to location. This information is considered for the selection of the best entry point , personal protection as well as means of extinguishing. If dangerous cargo is carried, it is important to look at the IMDG code for the extinguishing media selection (UN number, MFAG number) . For example, some dangerous goods can explode if water is used as extinguishing media.

Runners must be adequately trained for different fire scenarios and be aware of the firefighting methods to provide the best possible information to bridge team and to secure their own safety. Such knowledge should include the criteria for a safe entry, awareness of a dangerous situation and knowledge of counter measures which have to be undertaken. Special care must be taken if crew members are not normally involved in fire safety procedures for fire confirmation. The runners are not equipped with firefighting and safety equipment nor breathing apparatus. So, it is important that the fire location is evaluated for safe access.

See ANNEX A for Stena E-learning for fire patrol crew.

6.3.5 Continuous localization and confirmation during fire progress

Initial fire confirmation is crucial. Further, observations and confirmation about the development of a fire is important.

Experience from the car deck fire on Pearl of Scandinavia, 2010. showed that the smoke and heat have disabled all means including CCTV and smoke/heat detection, along with the progress of fire. Manual means were the only way to get the information from the site. The crew could not enter into the relevant area or get visual information due to the high smoke density. It was only possible to sense the increased temperature of the deck and bulkheads from the opposite side of the fire, and with that information assess the fire location and intensity. Consequently, the fire doors were partly opened to get the impression of the situation in the cargo area.

6.4 Proposal for development and restrictions

To ensure good and clear communication between bridge team and fire patrol, a set of linguistic expressions and using Simplified Technical English shall be defined for different situations, such as location, type of fire, emergency states, activities status etc. Further, communication pace, repetition of important messages etc. may be established. Currently, the terminology is very strict and direct, dependent on the situation, individuals, and stress level.

Systems for automatic positioning of the fire patrol can be evaluated.

Livestream photos/films from fire patrol/runner may be considered.

CCTV coverage and the possibility of automatic tracking of the fire patrol to be considered.

Horizontal marking (zone numbers, etc. on deck) to be considered. Reading from long distance shall be enabled.

Max. time for single task can be established, during which target information should be provided and communicated with bridge team. Max. time could be from 5 to 8 minutes, including the time to reach the location?

Standardized marking system for drencher zone (position, size, font of letters/numbers) to be considered.

Need of light breathing masks on all accesses to the cargo areas where toxic gases can be expected may be considered. It is to be noted that gas masks can only protect against certain gases and fumes. Care must be taken so that the operator is informed with that fact. Personal gas detectors can give alarm for toxic or combustible gases or low O_2-concentrations.

7 Efficient first response - Action 6-C

Main author of the chapter: Martin Carlsson, STL

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 6-C i.e. Efficient first response.

7.1 Short Description of the addressed Action

The objective of Action 6-C is to develop and validate smart technical solutions and tactics as well as to evaluate new equipment for quick first response and effective fighting of fires in their initial stage, through:

- Definitions of conditions for efficient first response
- Development and demonstration of effective first response firefighting tactics, gear and equipment
- Development and demonstration of smart alert of nearby first responders

7.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the rules and regulation requirements applicable in ro-ro spaces for the action 6-C .

7.2.1 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

Table 3: List of documents used for the review of regulations for Action 6-C

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
	MSC.1/Circ. 1432, as amended by IMO MSC.1/Circ.1516 “revised guidelines for the maintenance and inspection of fire protection systems and appliances”
	STCW convention, as amended
	FSS Code, as amended
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
	DNVGL Rules for the Classification of Ships, January 2017
	LR Rules and Regulations for the Classification of Ships, July 2016
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 28/12/17 edition
	US Coast Guard Code of Federal Regulations (CFR) 46, 2019 online edition
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

7.2.1.1 Ro-ro space, vehicle space and special category space

As per SOLAS II-2/3 [5]:

- "*Vehicle spaces are cargo spaces intended for carriage of motor vehicles with fuel in their tanks for their own propulsion.*"
- *"Ro-ro spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction."*[2]
- *"Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m."*

  Special category spaces are ro-ro spaces to which passengers have access, possibly during the voyage. Special category spaces are the most frequent type of closed ro-ro spaces on ro-ro passenger ships.

  It is to be noted that open ro-ro spaces are not considered as special category spaces.

7.2.1.2 Closed, open and weather deck

As per SOLAS II-2/3 [5]:

- A "*weather deck is a deck which is completely exposed to the weather from above and from at least two sides.*"

  IACS UI SC 86 [7] additionally details that: "For the purposes of Reg. II-2/19 a ro-ro space fully open above and with full openings in both ends may be treated as a weather deck."

  For practical purposes, drencher fire-extinguishing system cannot be fitted on weather decks due to the absence of deckhead. This criterion is often used for a practical definition of weather decks.
- An open vehicle or ro-ro space is "*either open at both ends or [has] an opening at one end and [is] provided with adequate natural ventilation effective over [its] entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides.*"
- A closed vehicle or ro-ro space is any vehicle or ro-ro space which is neither open nor a weather deck.
- As a reference criterion, it can be considered that a vehicle space that needs mechanical ventilation is a closed vehicle space.

7.2.2 Requirements

7.2.2.1 General

It is to be noted that first response to an emergency situation is, per se, an operational matter to be dealt on a case-by-case basis. Therefore, international regulations usually do not cover the first response itself, rather they give provisions to ensure that first response will be possible and relevant, requiring:

- Drills and procedures;
- Equipment; and

[2] In other words, ro-ro spaces are vehicle spaces into which vehicles can be driven. It is to be noted however that, for the purpose of the application of SOLAS II-2/19 [5], the following interpretation can be found in MSC.1/Circ.1120 [6] and IACS UI SC 85 [7]: "Ro-ro spaces include special category spaces and vehicle spaces".

- That the equipment is kept in working order.

7.2.2.2 Onboard organisation and crew training

SOLAS [5] includes general requirements requiring that emergency situations including fire scenarios are foreseen so as to ensure adequate first response: crew members are to be trained to react to fire situations, assigned with a relevant duty in case of a fire and be well aware of that duty. Associated drills and training are to be carried out regularly and all relevant manuals for the use of the fire-fighting or emergency response equipment are to be available on board. In addition, regular fire drills simulating evacuation scenarios are required on passenger ships. It should be noted that no specific training is required for passengers to carry out a first response in case of a fire.

[SOLAS II-2/15]

In addition to SOLAS [5], STCW Convention [26] specifies that all crew members shall receive appropriate approved basic training or instruction in fire prevention and fire-fighting. Table A-VI/1-2 provides the specification of minimum standard of competence in fire prevention and fire-fighting, i.e. competence, knowledge, understanding and proficiency, methods for demonstrating competence, and criteria for evaluating competence.

[STCW VI/A-VI/1 Table A-VI/1-2]

7.2.2.3 Operational readiness and maintenance

SOLAS [5] includes general requirements stating that:

- All fire safety systems are to be kept in proper working order. Especially portable fire-extinguishers are to be immediately replaced when they have been discharged.

[SOLAS II-2/14.2.1.2]

- Fire-fighting systems and appliances, including fire-fighter’s outfits and portable fire extinguishers, are to be regularly maintained and inspected.

[SOLAS II-2/14.2.2]

IMO [5] recommends the maintenance and inspection plan shown in Table 4 below for first-response-related equipment, to be completed by inspection and maintenance according to each manufacturer’s instructions. These inspections are to be carried out by the crew on a regular basis.

[IMO MSC.1/Circ.1432, as amended by IMO MSC.1/Circ.1516]

As a complement, Class Societies carry out third part surveys on a yearly, 3-yearly and 5-yearly basis.

Table 4: Minimum inspection and maintenance plan for first response equipment according to IMO MSC.1/Circ.1432 [5]

Equipment	Inspection and maintenance period				
	One Week	**One Month**	**One Year**	**Five Years**	**Ten years**
Breathing apparatus	Examine all breathing apparatus and EEBD (Emergency Escape Breathing Device) cylinder gauges to confirm they are in the correct pressure range.		- Check breathing apparatus air recharging systems, if fitted, for air quality; - Check all breathing apparatus face masks and air demand valves are in serviceable condition; and - Check EEBDs according to maker's instructions.	Perform hydrostatic testing of all steel self-contained breathing apparatus cylinders. Aluminium and composite cylinders should be tested to the satisfaction of the Administration.	
Portable foam applicators		Verify all portable foam applicators are in place, properly arranged, and are in proper condition.	- Verify all portable foam applicators are set to the correct proportioning ratio for the foam concentrate supplied and the equipment is in proper order; - Verify all portable containers or portable tanks containing foam concentrate remain factory sealed, and the manufacturer's recommended service life interval has not been exceeded; - Portable containers or portable tanks containing foam concentrate, excluding protein based concentrates, less than 10 years old, that remain factory sealed can normally be accepted without the periodical foam control tests required in MSC.1/Circ.1312 [27] being carried out; - Protein based foam concentrate portable containers and portable tanks should be thoroughly checked and, if more than five years old, the foam concentrate should be subjected to the periodical foam control tests required in MSC.1/Circ.1312 [27], or renewed; and - The foam concentrates of any non-sealed portable containers and portable tanks, and portable containers and portable tanks where production data is not documented, should be subjected to the periodical foam control tests required in MSC.1/Circ.1312 [27].		
Wheeled (mobile) fire extinguishers		Verify all extinguishers are in place, properly arranged, and are in proper condition.	- Perform periodical inspections in accordance with the manufacturer's instructions; - Visually inspect all accessible components for proper condition; - Check the hydrostatic test date of each cylinder; and - For dry powder extinguishers, invert extinguisher to ensure powder is agitated.	Visually examine at least one extinguisher of each type manufactured in the same year and kept on board.	All extinguishers together with propellant cartridges should be hydrostatically tested by specially trained persons in accordance with recognized standards or the manufacturer's instructions.

7.2.2.4 Equipment

A number of portable equipment are required on board in order to allow first response in case a fire starts in a vehicle or ro-ro space:

- Portable fire extinguishers are to be stored every 20 m within any vehicle or ro-ro open or closed space and at each access to the space.

[SOLAS II-2/20.6.2.1]

- 3 water-fog applicators are required in each ro-ro or vehicle open or closed space.

[SOLAS II-2/20.6.2.1]

- 1 portable foam applicator per ro-ro or vehicle open or closed space is also required, with at least 2 applicators to be available on board.

[SOLAS II-2/20.6.2.2]

FSS Code [21] provides more details about type approval and engineering specifications of fire extinguishers and portable foam applicators.

[FSS Code Ch 4]

In addition for passenger ships, it is to be noted that manually operated call points are to be provided every 20 m inside each special category space and close to each access to the space, as part of the fixed fire detection and fire alarm system.

[SOLAS II-2/20.4.3.2]

7.3 Operational aspects

7.3.1 First response definition and philosophy

The first few minutes in the development of a fire incident or a fire is of extreme importance. Quick and decisive action can terminate the fire incident before major damage is done, or at least slow down development and enable sufficient time for decisions and actions later in chain of event.

Proposed terminology, “First” used in LASHFIRE task, “Rapid” established by some operators:

First [or Rapid] response	The activity, can be performed by anyone
First [or Rapid] responder	Someone (anyone) acting in response to a fire
Designated First [or Rapid] responder	Designated person, specially prepared for response activity

To achieve above targets, the designated first responder should either be the fire patrol or similarly trained crew member. There is time for no hesitation in such situations, action must come immediately rather than elaboration. Also, the needed equipment must be ready at hand, at a known location and fully functioning. Training and proper personal protective equipment should ensure that first responder is physically and mentally fit for the task.

Distinction between first response vs firefighting and fire patrolling and logics behind such term must be established. Term “First response” means prompt reaction and arrival on the fire scene and readiness to take action to start extinguishing the fire or fire risk in early stage and report the situation. Mindset should be not only “first” but also “rapid”. Full task should be accomplished and reported in **preferably 60 seconds, and maximum within 3 minutes**, from fire alarm. This requires good mental preparedness of the person in charge.

Designated first responder and fire patrol should be well familiarized with the vessel in terms of accesses, escapes obstacles, best approach paths, adjacent spaces etc. Also, person in charge should be aware of the stowage situation, particularly regarding dangerous goods and alternative fuel vehicles location.

Officers should keep in mind that personnel appointed as designated first responder cannot be engaged in other work which makes it impossible to act as a first responder.

Designated first responders must, if assigned work that interferes with the possibility to act as first responder, notify superior to have a temporary replacement of the first response task.

At least one designated first responder should be appointed at all times for assignment in cargo spaces. Depending on type of operation, more than one may be appointed, for example one in deck department and one in technical department. However, any crew member may act to a fire in the spirit of first response, both in cargos spaces and other parts of vessel. Cases where more than one candidate is needed is when fire patrol is in a remote position on vessel and other crew members are closer to location of fire.

When looking into some major accident reports, what they all have in common is that there are no indications of any activity that can be regarded as “first response”. Possible causes:

1. Fire already too large at detection
2. No training/preparedness for “first response” action
3. Time slot available <u>after</u> detection but <u>before</u> fire growth but no suitable firefighting method at hand.

7.3.2 Awareness box: Fire sizes

A fire of medium growth rate reaches 50 kW after 1 minute. This is comparable to a burning paper bin and is easy to extinguish with a portable extinguisher. After 3 minutes the fire is significantly larger; 400 kW.

After 5 minutes it is about 1 MW which is the size of a 1 m2 diesel pool fire. Now it is difficult to put out with portable fire extinguishers.

The fire growth is exponential which means that after just another 2 minutes the fire has doubled in size to become a 2 MW fire.

7.3.3 Personal gear, PPE

It is important that a designated first responder, when approaching a possible fire, should wear long sleeve jacket/shirt and long trousers in a material that is not easily combustible, as outer layer of clothing. Typical material for coveralls, synthetic fibers, should be good but fleece and polyester are not recommended. Clothing shall be clean, not stained with oily content or similar that increase combustibility. A set of long sleeve protective gloves made of thin material and safety footwear should also be worn when approaching a fire. Idea is to cover bare skin as much as possible. A radio for communication should always be carried.

First response clothing and equipment shall be same as for fire patrol since it is expected that the fire patrol will carry out first response tasks when a fire is detected during patrol, or from bridge, triggered with other means of fire indication. Fire patrol shall also be equipped with a flash light and hand held heat camera. It is important that specification of fire patrol or any other able seaman general work gears consider fire resistance.

One important issue is the difference in conditions indoor/outdoor especially in bad weather and winter time. Appointed crew member need be ready for first response action at all locations onboard. Other important issue is that in practice a fire patrol outfit may vary depending on the tasks to be performed before or after patrol round, be it mooring operations in winter time or bridge outlook duties.

Correct gear is immensely important for first responder to provide him additional courage and confidence to act.

7.3.4 Training

First response should be part of scheduled fire drills onboard, for crewmembers normally appointed as designated first responder as well as for all crew members who may be in such a situation.

Topics to consider in regard to training for crew members being candidate for first responder task:

- Mental preparedness (awareness of the task)
- Physical preparedness (i.e. having the right PPE close at all times, even during normal daily work)
- Use of portable heat camera
- Ready for rapid decision
- Excellent familiarization with the actual vessel, escapes and access ways and limitations, keys, radio shadows, marking of drencher zones
- Familiarization with available firefighting equipment and locally stored PPE in every possible location onboard
- Skilled to use different types of extinguisher, fire blankets and other types of equipment
- Training in different scenarios with its standard procedures
- Awareness of other functions and hierarchy in safety organization
- Communication skills; technology and terminology
- Self-protection, what to avoid and what is safe

Topics of relevance for possible extended scope of first response:

- Skills in different cargo types and its hazard
- Basic DG, IMDG knowledge and firefighting options
- Basic vehicle and cargo knowledge, main switch locations, specific hazards, common problems etc.
- Electric power system awareness for reefers or charging of e-cars
- Shared experiences from other vessels and colleagues

Familiarization of the vessel and current situation onboard is to be considered, especially the following:

- New employees introduction is extremely important
- Transition period of new crew member until his full readiness, extra preparedness/overlap from other members of the watch.
- The fire patrol/first responder should be aware of the current stowage of cargo and vehicles, in particular dangerous goods.

7.3.5 Availability of equipment close to the fire scene

Equipment relevant for first response activities:

- Extinguishers, of different types
- Special equipment such as fire blankets
- Absorbents and gear for handling leakages

Such equipment must be readily available close to a possible fire scene.

7.3.6 Communication & localization

Important success factors:

- Familiarization with UHF radio equipment, channels to use, how to speak in clear way
- Terminology to use for predictable and understandable dialogue
- Awareness of any radio shadows onboard
- Awareness of alternative means of communication in case of radio shadow or malfunction of primary option.

A system for automatic alerting of key crew members is in operation on certain vessels. In a particular examples, the fire alarm system triggers the phone system switch board with a text message. The message is automatically relayed to pre-selected users' phones. Such message could be sent to potential first responders. Risk of reduced vigilance of recipients of such automated messages due to false alarms needs to be considered.

Most important for localization is to secure the spoken communication between any individual acting in the various spaces onboard and supporting functions on bridge or elsewhere.

There is also a risk that a crew member may get lost or hesitate about right direction, being inside the general or cargo spaces and faced with a sudden stress/adrenaline and low visibility situations in an unexpected incident. In such situations, when verbal communication cannot take place, automated localization function may support person of support team on site of incident.

7.3.7 Psychological factors

First step is to make clear what the term "first response" means and what tasks it includes, to avoid possible hesitation of person in charge.

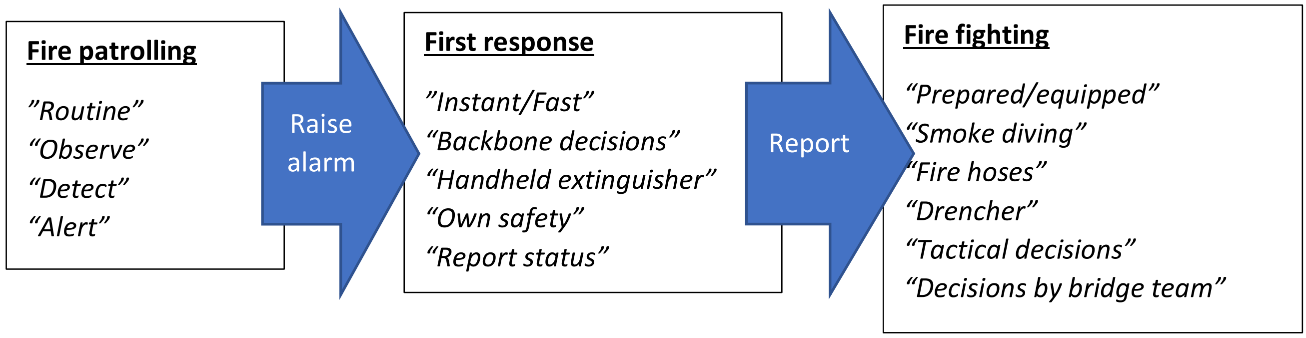
Many factors could influence the success of a first response action, many of them are related to certain person's mindset, courage, trust etc. Designated First Responder should be delegated based on his/her behavior in stressful situations and general profile of selected person during incidents. Person chosen for such a task should be then properly trained, familiarized with their clear tasks and reasonable expectations and equipped and familiarized with proper tools and PPE.

Delegations of authority and responsibilities must be very clear. Also, the working atmosphere onboard the vessel could influence the outcome of first response on fire scene.

It may be a challenge to balance the critical importance of correct and decisive actions during early stage of a fire with the expectation that most crew members should be ready and prepared to act in this respect.

7.3.8 Discussion of *fire patrol* vs *first response* vs *fire fighting*

Currently, there is no clearly defined functions and distinctions between *fire patrol* and *fire fighting* in neither rules nor reality. Introducing such would be of great contribution but must be made in clear way with care to avoid confusions. To add to the complexity, it may well be that the same person, while present on location acting as fire patrol, could switch into first response person, preparing for firefighting.



Depending on level of expectation for a first responder, the location of fire stations with access to proper light firefighting equipment could be relevant. Additional strategically located equipment such as breathing masks may be also considered. Assigning further advanced gear such as aerosol grenades and breathing device to a first responder could make the actual role too complex.

In order to open up discussion, below is described an approach of one operator:

The terms 'Discoverer' and 'Initial Response Team' is used – very different and impossible to confuse one from the other. It is also important to state that there should never be just a single 'designated first responder'. The second phase of response, called Initial Response Team, always consists of a minimum of 2 people. This is an important safety point because nobody should ever proceed to the scene of fire/smoke alone.

Regarding the drencher; once our Initial Response Team leader (who is always the Chief Officer) has completed his initial assessment they are to initiate next steps/actions which in most cases (for car deck fires) will include activation of the drencher system. Typically this will occur within 2-3 minutes of the raising of the initial alarm. If procedure is conducted in proper way, the drencher should already be 'on' by the time the ship is at Emergency Stations. This is all possible because of the rapid reaction provided by the Initial Response Team who, importantly, proceed directly to the scene of the smoke/fire without dressing in fire suits and breathing apparatus.

7.3.9 Scenarios

Crew members expected to act as designated first responder in cargo spaces must be familiar to the most common and critical (potential) fire situations.

Potential fire situations:

- Liquid fuel leakage
- Overheated/melting cables/sockets
- EV thermal runaway
- Gas leakage
- Self-heating cargo
- Overheating reefer unit belts

Fire situations may be:

- Cable (smoldering) fire
- Gas vehicle fire
- Electric vehicle (battery) fires
- Reefer cooling unit fire, fuel based or electric

- Open liquid fuel fire
- Cargo fires
- Electric device fire inside car or drivers cabin

For each case, the crewmember must be aware of risks and be skilled in how to act.

Designated first responder candidates also should have basic awareness of the risk characteristics of vehicle types:

- Electric vehicles
- Liquified gas vehicles
- Compressed gas vehicles
- Fossil fuel vehicles
- Most common IMDG cargo

7.4 Design and production aspects

The following aspects shall be considered:

- Logical and easy access points and access ways
- Clear marking and signage
- Communication availability ensured from all locations on the vessel

7.5 Proposal for development and restrictions

7.5.1 Development proposals

Proposals for developments are listed below:

- Plan and design the assignment in most efficient way;
    - Best function fit between fire patrol and firefighting team
    - Best position on the scale between extreme options of (1) an officially appointed, prepared, highly skilled and trained first responder and (2) first response as something most crew should be able to engage in, if only in right place at the right time
- Develop a standard function description to increase awareness of first response concept, since this concept is non existing today
- Establish a standard training plan for first response, including also officer delegating this responsibility.
- Develop electronic or other learning material than can be shared across the ro-ro/ro-pax industry.
- Investigate method/equipment to extend the usability of fire extinguisher to less accessible locations of possible fire such as high places on top of cabins, reefer units.
- Develop special instructions for electric and gas vehicles. Special focus on identifying type of vehicle, detection of risk indicators, safe approach, thermal runaway confirmation.
- Develop standard communication terminology protocol to secure prompt understanding.
- Investigate smartphone based solutions for information sharing to/from first responder. Investigate decision support.

7.5.2 Restrictions

Some system proposal for localization requires access to wireless communication, be it Wi-Fi or 3G/4G/5G systems or other specialized transponder system.

Mobile network coverage is limited to certain distance from shore and will be unavailable on most parts of voyage, especially on longer routes.

Radio-linked mobile network could be one of the solutions, when signal is sent to vessel by one directional radio transceiver in each end port.

Wi-Fi coverage on cargo decks may vary from none to full coverage. Since being less technology dependent, Wi-Fi is the likely future solution for communication in cargo areas onboard, as well as for any connectivity onboard.

Other type of localization may be based on image/object recognition, but the developer of such system should be aware of very narrow open spaces in vehicle garages in case of fully loaded condition. Also, such system should be easily customizable due to the fact that the cargo configuration at each port is redefined.

8 Effective and efficient manual firefighting- Action 6-D

Main author of the chapter: Martin Carlsson, STL

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 6-D i.e. effective and efficient manual firefighting requirements definition.

8.1 Short Description of the addressed Action

The objective of Action 6-D is to develop guidelines and a training module for firefighting of alternative fuel vehicles in ro-ro spaces, based on evaluation and full-scale demonstration of new equipment, through:

- Definitions of conditions for effective and efficient manual firefighting
- Development and full-scale testing of APV firefighting routines and equipment

8.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the rules and regulation requirements applicable in ro-ro spaces for the action 6-D .

8.2.1 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

Table 5. List of documents used for the review of regulations for Action 6-D

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
	MSC.1/Circ. 1432, as amended by IMO MSC.1/Circ.1516 “revised guidelines for the maintenance and inspection of fire protection systems and appliances”
	STCW convention, as amended
	FSS Code, as amended
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
	DNVGL Rules for the Classification of Ships, January 2017
	LR Rules and Regulations for the Classification of Ships, July 2016
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 28/12/17 edition
	US Coast Guard Code of Federal Regulations (CFR) 46, 2019 online edition
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

8.2.1.1 Ro-ro space, vehicle space and special category space

As per SOLAS II-2/3 [5]:

- *"Vehicle spaces are cargo spaces intended for carriage of motor vehicles with fuel in their tanks for their own propulsion."*
- *"Ro-ro spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction."*[3]
- *"Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m."*

  Special category spaces are ro-ro spaces to which passengers have access, possibly during the voyage. Special category spaces are the most frequent type of closed ro-ro spaces on ro-ro passenger ships.

  It is to be noted that open ro-ro spaces are not considered as special category spaces.

8.2.1.2 Closed, open and weather deck

As per SOLAS II-2/3 [5]:

- A "*weather deck is a deck which is completely exposed to the weather from above and from at least two sides.*"

  IACS UI SC 86 [7] additionally details that: "For the purposes of Reg. II-2/19 a ro-ro space fully open above and with full openings in both ends may be treated as a weather deck."

  For practical purposes, drencher fire-extinguishing system cannot be fitted on weather decks due to the absence of deckhead. This criterion is often used for a practical definition of weather decks.
- An open vehicle or ro-ro space is "*either open at both ends or [has] an opening at one end and [is] provided with adequate natural ventilation effective over [its] entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides.*"
- A closed vehicle or ro-ro space is any vehicle or ro-ro space which is neither open nor a weather deck.

  As a reference criterion, it can be considered that a vehicle space that needs mechanical ventilation is a closed vehicle space.

8.2.1.3 Fire-fighter's outfit

As per FSS Code Ch 3 [9], a fire fighter's outfit consists of a set of personal equipment and a self-contained air-breathing apparatus. As a note, a 30 m lifeline is also required with each air breathing apparatus.

[FSS Code Ch 3 §2.1.3]

[3] In other words, ro-ro spaces are vehicle spaces into which vehicles can be driven. It is to be noted however that, for the purpose of the application of SOLAS II-2/19 [5], the following interpretation can be found in MSC.1/Circ.1120 [6] and IACS UI SC 85 [7]: "Ro-ro spaces include special category spaces and vehicle spaces".

8.2.1.4 Personal equipment

A set of personal equipment means:

- Water-resistant and heat-protective clothing;
- Non-conducting (rubber) boots;
- Rigid helmet;
- Electric safety lamp with 3 hours autonomy; and
- Axe (handle with high-voltage insulation).

[FSS Code Ch 3 §2.1.1]

8.2.2 Requirements

8.2.2.1 General

International regulations effectively foresee manual fire-fighting insofar as they give provisions for:

- Drills and procedures;
- Manual fire-fighting equipment;
- Fire-fighter personal protection equipment; and
- Keeping the relevant equipment in working order.

8.2.2.2 Onboard organisation and crew training

SOLAS [5] includes general requirements requiring that emergency situations including fire scenarios are foreseen so as to ensure efficient manual fire-fighting: crew members are to be trained to react to fire situations, assigned with a relevant duty in case of a fire and be well aware of that duty. Associated drills and training are to be carried out regularly and all relevant manuals for the use of the fire-fighting or emergency response equipment are to be available on board.

In addition, regular fire drills are required on passenger ships.

[SOLAS II-2/15]

In addition to SOLAS [5], STCW Convention [26] specifies that all crew members shall receive appropriate approved basic training or instruction in fire prevention and fire-fighting. Table A-VI/1-2 provides the specification of minimum standard of competence in fire prevention and fire-fighting, i.e. competence, knowledge, understanding and proficiency, methods for demonstrating competence, and criteria for evaluating competence.

[STCW VI/A-VI/1 Table A-VI/1-2]

For crew members designated to control fire-fighting operations, they shall have successfully completed advanced training in techniques for fighting fire, in accordance with the STCW Code. In particular, Ch VI Section A-VI/3 and Table A-VI/3 provide the mandatory minimum standard of competence in advanced firefighting.

[STCW VI/A-VI/3 and Table A-VI/3]

8.2.2.3 Operational readiness and maintenance

SOLAS [5] includes general requirements stating that:

- All fire safety systems are to be kept in proper working order. Especially portable fire-extinguishers are to be immediately replaced when they have been discharged.

[SOLAS II-2/14.2.1.2]

- Fire-fighting systems and appliances, including fire-fighter's outfits and portable fire extinguishers, are to be regularly maintained and inspected.

[SOLAS II-2/14.2.2]

IMO [26] recommends the maintenance and inspection plan shown in Table 4 below for manual fire-fighting equipment, to be completed by inspection and maintenance according to each manufacturer's instructions. These inspections are to be carried out by the crew on a regular basis.

[IMO MSC.1/Circ.1432, as amended by IMO MSC.1/Circ.1516]

As a complement, Class Societies carry out third part surveys on a yearly, 3-yearly and 5-yearly basis.

8.3 Operational aspects

8.3.1 General conditions

8.3.1.1 Fire stations and equipment

Normally two main fire stations and few further spare stations are arranged on a vessel. Common location for Fire Station 1 is outside, usually on a weather deck, and for Fire Station 2 in the vicinity of the engine control room.

Spare fire stations may be located in any suitable location in the vessel.

Communication within the fire team is secured using UHF band radio, one channel per internal fire team. Communication with the bridge team is maintained by firefighting team leader on UHF, but on a dedicated channel. This means that physically two radio units for the firefighting team leader are always needed simultaneously. Present challenges with communication are radio coverage and function.

Protective clothing and equipment are essential for the safety and confidence of the crew. Reference is made to Safe and Suitable firefighting-project by RISE [33], establishing a marine specification for fire suits, and to MSB report on performance of fire suit to HF gases [31].

8.3.1.2 Fire teams

Normally one or two fire teams are organized onboard. If two teams are organized, most commonly one team is based on deck crew, whom will be first out on a cargo space or accommodation fire, while the other team is based on engine crew, whom will be first out on engine room and machinery spaces fire. If only one team is organized, it is based on a mix of crew. There are also other crew members identified as reserve if additional resources are need.

Allowed elapsed time from activation to full standby on site can be different during night and daytime but in general it is to be 10 minutes and 15 minutes respectively.

What can be expected from a fire team is related to many things, as will be described in the following sections. One part is the physical capacity of its members depending on age, gender and physical fitness. In shore-based fire brigades physical exercise is high on daily agenda and part of the description of work. This is not so relevant in the case of a crew onboard, although there are ways to encourage the crew members, especially the one designated as first response team, to maintain personal fitness.

Sometimes, specially trained shore-based fire-fighting teams (MIRG teams) are provided for support to vessels, either on arrival to port or embarked to the vessel still under way. Such assistance could be of great importance in extensive fire scenarios.

8.3.1.3 Conditions for activities

Primary purpose with any manual activity in a high-risk location is to save lives, either directly on the scene or indirectly via critical activities that prevents or delays fire spread, thereby safeguarding the ship and its crew and passengers.

The way people and teams operate is highly dependent on culture. This may be the influence of the culture of the vessel, between officers and crew or peers, it may be of the culture of the company or of a country of origin, as well as relation to other present cultures onboard. It should be made very clear what is expected from each individual, and also validated through drills and daily work that such expectations can be eventually met.

Important factor to consider is also the difference between an onboard fire group and a land based professional fire brigade. Onboard team rarely, if ever, encounter a real fire, while fire brigades' ashore handle fires frequently. This must be taken into consideration when discussing capabilities, methods and expectations. Ship fire teams skills are built by training and drills only and luckily, very occasionally on real situations.

In such context, the performance and proper use of fixed fire suppression system is of extreme importance, minimizing the crew exposure for demanding situations, but focusing to, more or less, lifesaving only or status checks.

For reasons mentioned above, it is essential to create rich and educative drill scenarios, since this is extremely significant part of the maintenance and development of firefighting skills of the crew. It is of high importance to perform training sessions in a fully loaded environment, as often as possible.

For many reasons, drencher system should be activated in an early stage of a fire. This means that manual firefighting needs to be coordinated with a drencher operation before approaching a fire location. Depending on the situation, it is necessary to either keep the drencher shut off or kept flooding, with the crew being soaked by potentially freezing cold sea water as a result. In the latter case, it shall be taken into consideration that such situation reduces the ability of the crew. On the other hand, drencher system will continue to suppress the fire and wash out the smoke and gases. This lack of help when drencher system is off must be compensated with the appropriate value of manual intervention.

For Vehicle Carriers, the fixed fire-fighting system, normally CO2-low pressure system, is activated after other means of extinguishment has been considered and attempted. No manual firefighting can continue or start after the CO2-system has been activated. The cargo space must be evacuated and all openings to be closed and remain closed. (Ref Chapter 18)

Cargo stowage, especially at fully loaded conditions, is in many cases a challenge. Distance between units may be very small (please refer to 20), and also the cargo may move, due to vehicle suspension system flexibility, which may lead to injuries of the crew or getting stuck. The stowage situation will influence both the safe movement of crew, especially with fire-fighting gear and handling of fire-fighting equipment as well as unobstructed pressurizing of hoses.

In Vehicle Carriers the stowage is done with minimal distance in between the vehicles so that it is practically impossible for a fire team to access a fire within a “block” which could consist of hundreds of vehicles. All cargo is secured at sea by web lashings or chain lashings which makes access even more difficult.

Access to the fire origin is also hindered where shielded under tarpaulin covers, inside rigid cargo units or inside cabins of vehicles. Such conditions may hinder accurate observations and decisions.

Further, fire origin may be located in a high or low position, making the observations and access challenging.

For additional information on the topic please refer to Chapter 7.

8.3.2 Presently available and potential manual equipment

Presently available and potential manual equipment is listed and described as follows:

- **Fireman's IR camera** (harsh condition and heat resistant) is handy for detailed investigation related to overheating and temperature trends. Remote observations possible.
- **Gas detector** is in some cases stipulated for vehicle carriers to be available onboard and may be brought to the scene in order to better understand the situation or to check if the atmosphere is safe.
- **Fire extinguisher** of different types
- **Fire blankets** may be an option in certain cases, however there are challenges and limitations [4]. In order to apply a fire blanket properly on a car fire, the fire team need to act in close proximity to the fire. Also, the fire blanket need to be placed accurately to reach the maximum expected performance.
- **Passive water-cooling device** (boundary or direct)
- **Fog nails** suitable for ingress and water mist application of closed spaces such as truck cabins, cargo containers, covered trailers, without opening up for oxygen supply.
- **Classic hose with water**, to be used for classic cooling at a distance
- **Foam equipment** for liquid fires

8.3.3 APV aspects

Ro-ro vessel crews are familiar to the risks, early signs and countermeasures related to the liquid flammable fuel vehicles. At present, similar skills need to be established for new types of drive lines i.e. APVs.

At present operations of ro-ro and ro-pax ships it is not always possible to have the information on the vehicles driveline. On Vehicle carriers in the transportation of new cars, or checked used cars, there are other possibilities to label APV's and also to include typical APV-information on the cargo loading plan, depending however on the operator's standards and routines. Generally, it is preferable to have one common manual activity methodology regardless off the driveline.

Ventilation management is important to safeguard crew members actively in a cargo space. The crew must be familiar to the ventilation system to achieve the desired safe airflow which should be practiced during the drills. The best situation would be if a fire scenario-based ventilation modes are predefined, activated by a single command.

All modern vehicles burn with highly hazardous gases, where Li-Ion batteries contributes to HF. Due to the challenges to succeed with final extinguishment of a battery fire, smoke/gas emission must be anticipated during an extended time period compared to a case where a fossil fuelled car fire is extinguished before all fire energy is released.

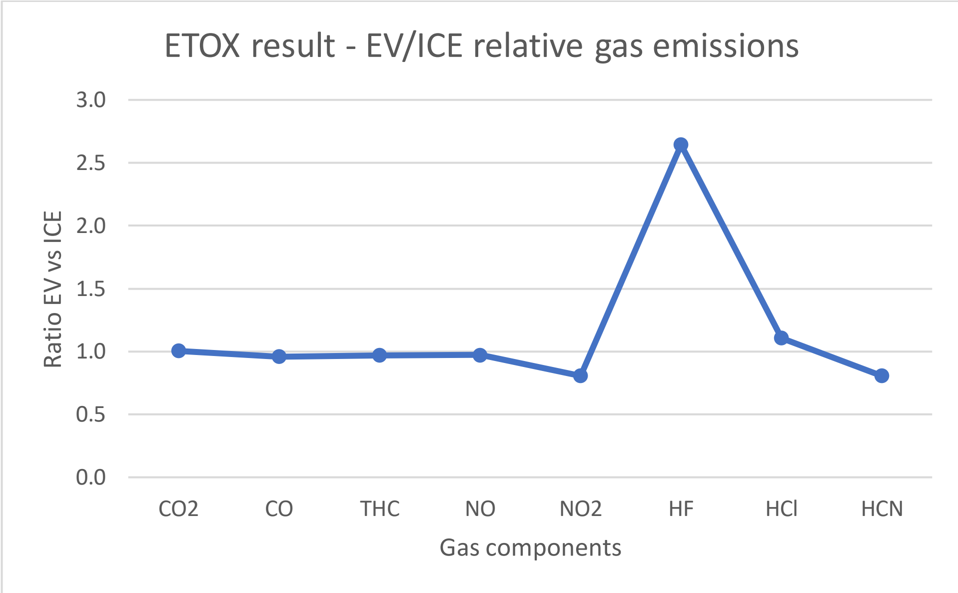


Figure 2. Comparison of amounts of released gas components from fully burned cars of EV and ICE type.

Fire team skin and breathing protection with proper use of breathing apparatus and fire suit with hand and foot gear is hereby essential. Recent studies [31] have proven that proper use of adequate equipment protects well, faced with such fire.

Due to the hazardous gases and risk of exposure of the crew to severe situations, the use of portable devices for cooling and boundary cooling may be suitable. Such devices should be possible to put in place by manual action, within as large as possible safety distance from the hazard.

Different safety precautions may be needed when approaching gas vehicles, electric vehicles or fossil fuel vehicles due to the variation in ignition, fire growth and fire spread characteristics. However, to reduce the complexity for crew, the objective should be to establish one single methodology valid for all types of vehicles.

Compressed gas vehicles (CGV) pose a certain risk if the gas tank is heated which could lead to a jet-flame or in worst case an explosion if the safety valve fails or if the valve is cooled down unintentionally. If there is a fire near a gas tank a safe distance must be established which probably means that the cargo space has to be evacuated.

Special methods may be required for unloading of damaged APVs ashore, which should be known to the crew and shore-based functions. Such methods should be mentioned in the Emergency Card.

At present, the number of transported APVs is low, but steadily growing and, in the near future, may make the majority of the vehicles onboard. This fact shall be considered during the development of firefighting methods.

References to RelyNutec paper [30], proposing a methodology for manual fire-fighting of AFVs fire.

Reference to ELBAS project by Dansk Brand Institut [37].

8.3.4 Post mission treatment of crew and gear

Post mission treatment of the crew, gear and PPE need to be established. The first step is the treatment of smoke diving teams at exit from the space of a fire event. The objective of the treatment is to relief the crew from exposure and isolate potentially contaminated equipment without further exposure to the support team and contamination of adjacent spaces. The following step is to ensure that the exposed smoke divers exit the hazardous area and are subject to an adequate treatment such as shower, fresh drinking water and fresh air.

Inspiration can be found from chemical incident operations.

8.4 Design and production aspects

Size and layout of fire stations must be selected to ensure efficient mustering and gearing of crew as well as safe demobilization. This should include treatment of the team members and equipment from exposure of hazardous substances. Such post mission treatment locations must also be organized in immediate vicinity of the scene of event, in order to avoid contamination of clean spaces.

Predefined/programmed cargo-space ventilation operation modes that, depending on the location of a fire, gives best conditions for approach, may be established.

Main and alternative access points and paths to fire scene should be predefined to speed up the decision making process in a fire event.

8.5 Environmental aspects

Fires in vehicles will emit smoke and toxic gases that could pose immediate threat to human or other life, or could spread to and accumulate on surfaces with risk of subsequent secondary exposure.

Extinguishing water from EVs will include toxic component that may be harmful for the environment. This will be investigated in E-TOX2 where toxic substances in extinguishing water from conventional cars, electric vehicles and standalone batteries will be quantified as well as its environmental impact. Also, the effect of drencher water gas wash-out will be investigated.

8.6 Proposal for development and restrictions

Proposals for developments and restrictions are listed below.

Development of an APV characteristics information overview sheet, such as shown in the following table is to be considered.

Table 6. Idea of a AVF drive line type characteristics overview.

Parameter	General car	ICE	HEV	EV	LNG	LPG	CNG	Hydrogen
Energy carrier	Plastic material, rubber,textile etc	Petrol, Diesel	NiCd battery & Petrol	Li-Ion battery	Liquified CH_4	Liguified Butane & Propane	Compressed CH_4	Liquified H_2
Tank pressure	N/A	Ambient	N/A	N/A	12 bar	12 bar	200 bar	200 bar
Gas form density relative air	N/A	N/A	N/A	Heavier	Lighter	Heavier	Lighter	Lighter
Odour/visibility	N/A	Liquid	Liquid	??/White	No/No			
Toxicity (pre-fire)	N/A	N/A	N/A	Yes	Asphyxiant		Asphyxiant	Asphyxiant
Stowage advice	N/A	N/A	N/A		Preferrably open decks	Preferrably open decks	Preferrably open decks, avoid corners	Preferrably open decks, avoid corners
Pre-ignition signs of malfunction	Smoke, heat	Fuel leak	Fuel leak	Heavy smoke & heat 50-80 deg from battery. Popping sounds from battery cells	Noise from pressure release valve. Smell of venting gases.	Noise from pressure release valve. Smell of venting gases.	Noise from pressure release valve. Smell of venting gases.	Noise from pressure release valve.
Ignition	Electric heat/ spark	Electric heat/ spark	Electric heat/ spark	Battery heat, external heat/spark	Ext[illegible]rnal he[illegible]/spark	External heat/spark	External heat/spark	External heat/spark
Fire characteristics	Plastic, Carbon fibre Al/Mg-alloys, misc Violent fire	Pool fire	Pool fire	Unpredicta[illegible]aks due to bu[illegible]ing c[illegible]s. Explos[illegible]n i[illegible]d ig[illegible]n.	Jet [illegible]e from boil off [illegible]alve. BLEVE Fire ball Explosion if delayed ignition	Jet fire from boil off valve. BLEVE Fire ball Explosion if delayed ignition	Jet fire from PRV Explosion if delayed ignition Explosion of tank if heated and no pressure release	Jet fire from PRV Explosion if delayed ignition Explosion of tank if heated and no pressure release
Modes of fire spread	Heat	Fuel pool	[illegible]el p[illegible]	Short lived jet flames 1-5 m Scatter of hot objects, mainly for cylindrical cells	Jet flame 1-3 m Tank explosion	Jet flame 1-3 m Tank explosion	Jet flame 10 -25 m Tank explosion	Jet flame 10 -25 m Tank explosion
Main hazards	Haz gases Exploding tyres, airbags, gas springs	Fuel pool	Fuel pool	Thermal run-away gas release, explosion/ignition risk. Unpredictable battery contribution 50% extra HF gas from fire compared to	Gas boil off Tank explosion	Gas boil off Tank explosion	Extensive jet flame Tank explosion	Extensive jet flame Tank explosion
Suppression	Water/Powder/ Foam	Water/Foam	Water/Foam	Water, under vehicle	Water on tank	Water on tank	Water on tank	Water on tank
Containment	Drencher Hose	Drencher/Foam	Drencher/Foam	Drencher/extra water	Drencher	Drencher	Drencher	Drencher
Post fire	Cool until temp is low	Cool until temp is low	Cool until temp is low	Must be monitored, risk of spontaneous re-ignition	Cool until temp is low. Maintain safe distance XX m to tank	Cool until temp is low. Maintain safe distance XX m to tank	Cool until temp is low. Maintain safe distance XX m to tank	Cool until temp is low. Maintain safe distance XX m to tank

Step by step event sequence decision support shall be assessed, considering possible chains of events and objects involved in the incident. The target should be to define one general approach to avoid complexity, where specific statements shall be specified for eventual special consideration of an event. Fire incident steps to consider:

1. Indication
2. Detection
3. Confirmation
4. Rapid response
5. Fixed system activation
6. Fire team mustering
7. Fire team approach to scene
8. Manual life saving
9. Manual fire suppression
10. Manual fire containment
11. Situation development follow-up
12. Escalation
13. Fire team post-mission treatment
14. Post fire activities

For each step, recommended considerations and actions to be listed for any involved objects if different from the generally applicable approach:

a) ICE vehicle
b) E vehicle
c) LNG vehicle
d) CNG vehicle
e) Hydrogen vehicles
f) Minor e-vehicle

Above list may also be expanded to traditional hazard objects:

- DG
- Reefers
- RV with aux energy source
- ICE heavy vehicle

Else to consider:

- Usage guidelines for specific pieces of equipment.
- “Fire-fighting by space”, information on the space-of-incident and adjacent spaces to speed up decision process and make sure no mistakes are made due to the lack or wrong data.
- Land based online emergency response decision support centres for crew.
- Support app on phone for decision makers of fire teams.
- Guidelines for post-mission treatment of crew and gear

9 Improved bridge alarm panel design - Action 7-A

Main author of the chapter: Sif Lundsvig, DFDS

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 7-A i.e. Improved bridge alarm panel design, and is based on a survey of vessels in the DFDS fleet and with input from marine standards and new builds department.

It must be mentioned that many different IAMCS systems are co-existing on board the world fleet, and that this Chapter is trying to highlight common problems. This said all systems are not known to the author and thus there may exists systems that are already trying to take care of some of the addressed problems.

9.1 Short Description of the addressed Action

Reduced potential for human error, accelerating time sensitive tasks and providing more comprehensive and effective decision support, by increased uptake of human centred design and improved design of tools, environments, methods and processes for critical operations in case of fire. Action 7-A is aiming to Re-design and develop guidelines for improved fire detection system interface design, promoting intuitive operations and quick decision-making. This shall be achived through:

- Definition of conditions for improved fire detection system interface design
- Questionnaire and interview study on detection system design
- Development of guidelines, process and methods for improved fire detection interface design
- Demonstration and validation of guidelines and development of alarm system interface prototype

9.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 7-A.

9.2.1 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships. As an indication, FSS Code Chapter 9, dedicated to fixed fire detection systems was fully reviewed through MSC.311(88) and applies to ships the keel of which was laid after 01/07/2012. However, only few significant changes in the regulations were identified over the last 40 years.

A brief summary of the main regulation changes related to Improved fire detection system interface design is provided in Table 7 with a particular focus on regulations relevant to Action 7-A. The review is mainly based on the documents listed in Table 8.

Table 7. Summary of regulation changes

Regulation change	Application date	Adoption date	Summary
SOLAS 74	1980[4]	1974	Introduces the principle of horizontal fire zone for ro-ro spaces / special category spaces with: - Structural fire protection - Fixed fire extinguishing system ("drencher" type) - Fixed fire detection system
MSC.1/Circ.1272	2008	-	Allows fixed water-mist fire-extinguishing systems Allows automatic release associated with some requirements related to fire detection
MSC.217(82)	2010	2006	Requires addressable fixed fire detection and fire alarm systems on passenger ships
MSC.311(88)	2012	2010	Revision of FSS Code Ch.9

[4] It is to be noted that the concept of horizontal fire zone and associated safety measures has actually been introduced in SOLAS 60 part H as per IMO resolution A.122(V) dated October 1967. However, the circular was never made mandatory and Part H was therefore only applied on a voluntary basis until SOLAS 74 came into force. Compliance with Part H is formally recognized to be equivalent with SOLAS 74.

Table 8. List of documents used for the review of regulations for Improved fire detection system interface design

IMO Documents	SOLAS Convention, as amended
	Fire Safety Systems (FSS) Code, as amended in 2017
	MSC.1/Circ.1430 – Revised guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces, May 31, 2012
	MSC.1/Circ.1615 – Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	UI SC35 rev.3 – July 2013 "Fixed Fire Detection and Fire Alarm System"
	UI SC73 rev.2 – Nov. 2005 "Fire protection of weather decks"
	UI SC117 rev.2 – Nov. 2005 "Fire detection system with remotely and individually identifiable detectors"
	UR E22 rev.2 – June 2016 "On Board Use and Application of Computer based systems"
	BV Rules for Steel Ship (NR467), as amended in January 2018
Flag Administration Rules	MMF (French Flag Administration) Division 221 "Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage", 28/12/17 edition
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

9.2.2 Requirements

9.2.2.1 General

This section describes the general requirements related to Improved fire detection system interface design and provides the associated reference(s) in the regulatory texts. This section addresses fixed fire detection and fire alarm systems with a particular focus on the system interface. Interested readers are invited to refer to IR04.4 and IR04.5 for more information on fire detectors.

SOLAS II-2/20.4.1 requires a fixed fire detection and fire alarm system to be fitted in all ro-ro spaces.

It is widely accepted however that no fixed fire detection and fire alarm system is required on weather decks used for the carriage of vehicle with fuel in their tanks as per IACS interpretation UI SC73.

It is to be noted that fire detection is required on open ro-ro spaces (although some discussion on this point regularly arises at shipbuilding phase).

9.2.2.1.1 Type of fixed fire detection system

SOLAS II-2/20.4.1 requires a standard fixed fire detection and alarm system in line with FSS Code requirements.

9.2.2.1.1.1 Passenger ships

Unless an efficient continuous fire watch is performed, a fixed fire alarm and fire detection system is required in open and closed ro-ro spaces of passenger ships and it is worth noting that sample extraction smoke detection systems are not allowed on passenger ships vehicle spaces since SOLAS II-2/20.4.2 prohibits such systems[5] in "*open ro-ro spaces, open vehicle spaces and special category spaces*".

In addition, on passenger ships constructed in or after 2010, the system is to be addressable i.e. capable of identifying remotely and individually each detector and manually operated call point (FSS Code Ch. 9 §2.1.7). Before 2010, the fixed fire detection system was required to be divided into sections, and to be able to indicate in which section a detector has been activated.

MSC.1/Circ.1615 further proposes it on existing ships:

> "2.1 Addressable fixed fire detection and alarm systems
>
> 2.1.1 For ships built before July 2010, it is recommended that a fixed fire detection and alarm system with individually addressable detectors be considered to replace existing systems in ro-ro spaces and special category spaces."

It is to be noted however that MSC.1/Circ.1615 is a mere guideline, therefore applicable only on a voluntary basis, and targets only passenger ships.

9.2.2.1.1.2 Cargo ships

SOLAS II-2/20.4.2 allows sample extraction smoke detection systems except in "open ro-ro spaces, open vehicle spaces" as an alternative for the fixed fire detection and fire alarm system required in SOLAS II-2/20.4.1. The systems shall be compliant with the requirements with the FSS Code [FSS Code Ch. 10].

9.2.2.2 Fixed fire detection and fire alarm systems

This section describes the performance expected from, and the requirements of, the fixed fire detection and fire alarm, as detailed in the standards and regulations, with a particular focus on the system interface.

The fire detection system is to include fire detectors and manually operated call points.

9.2.2.2.1 General

FSS Code Ch. 9 §2.1.2 lists the following main functionalities for the fire detection system:

- "control and monitor input signals from all connected fire and smoke detectors and manual call points;
- provide output signals to the navigation bridge, continuously manned central control station or onboard safety centre to notify the crew of fire and fault conditions;
- monitor power supplies and circuits necessary for the operation of the system for loss of power and fault conditions; and

[5] Sample extraction smoke systems have been prohibited in SOLAS 1989 amendments (MSC.13(57)), applicable to ships constructed on or after 1 February 1992. As far as BV knows, this was a consequence of the bad service conditions observed on ro-ro ships for such systems (pipe ageing and corrosion) which usually had a common steel piping with the gas fire-extinguishing system.

- *the system may be arranged with output signals to other fire safety systems*" (communication, alarm and public address systems, ventilation, fire doors and fire dampers, fire extinguishing and systems supporting evacuation such as Low Location Lighting (LLL))

9.2.2.2.2 Certification and Maintenance

FSS Code Ch. 9 §2.1.5: All components are to be qualified for operation in marine environment (standard requirements for electrical equipment onboard ships). In addition, all electrical and electronic equipment on the bridge or in the vicinity of the bridge shall be tested for electromagnetic compatibility.

The control panel is to be tested according to standards EN 54-2:1997, EN 54-4:1997 and IEC 60092-504:2001 (FSS Ch. 9 §2.3.2)

In-service testing and proper maintenance are required in FSS Ch. 9 §2.5.2, SOLAS II-2/7.3 & SOLAS II-2/14.2.2.

9.2.2.2.3 Alarm

The activation of any detector or manually operated call point is to initiate a visual and audible alarm at each indicating unit, i.e. at least at the safety centre and at the navigation bridge.

After 2 minutes, if the alarm has not been acknowledged, an audible fire alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of category A (FSS Ch. 9 §2.5.1).

The first initiated fire alarm is not to prevent any other detector from initiating further fire alarms as per FSS Code Ch. 9 §2.1.6.3, applicable to addressable systems.

In addition, a special alarm is required by SOLAS II-2/7.9.4, in order to allow summoning the crew from the navigation bridge or safety centre.

Sound pressure levels are given in FSS Ch. 9 §2.5.1.9.

MSC.1/Circ.1615 further proposes:

> "2.5 Alarm system design and integration
>
> Alarm notifications should follow a consistent alarm presentation scheme (wording, vocabulary, colour, and position) and that alarms are immediately recognizable on the bridge and not compromised by noise or poor placing. The interface should provide alarm addressability to allow the crew to identify the alarm history, the most recent alarm, and the means to suppress alarms while ensuring the alarms with ongoing trigger conditions are still clearly visible."

9.2.2.2.4 Information exchange and interaction with other systems

In general, FSS Code Ch. 9 §2.1.3 and §2.1.2 limit the interaction of the fire detection system with other systems to output signals sent to other safety systems. However, it allows the fire detection system to be connected to a decision management system[6] provided this decision management

[6] A decision management system refers to a system able to gather information from several other sub-systems such as ventilation, fire detection, fuel level, fire doors etc. and will support ship management for e.g.:

- Dealing with an emergency by displaying all relevant information on one terminal, helping identifying the emergency scenario and proposing detailed action lists to tackle the emergency
- Training by simulating emergencies

system can be disconnected without impact on the required functionalities for the fire detection system. It is also required that malfunction of the decision management system will not propagate into the fire detection system.

IACS UR E22 reckons the fire detection system as a category III, i.e. in case of fire, its failure could "*immediately lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment*". It therefore sets a number of requirements for the system supporting software development and testing process, aiming at ensuring its operational reliability.

In addition, MSC.1/Circ.1430 makes it clear that the fire detection system may control the release of the water-based fixed fire-fighting system in the vehicle space, in case the fixed fire-extinguishing system is a manual deluge system, automatic deluge system or pre-action system[7].

9.2.2.2.5 Section arrangement

The system is to be organized into sections as per FSS Code Ch. 9 §2.1.4 and 2.4.1.1.

On passenger ships, fire detection sections are not allowed to cover more than one Main Vertical Zone (MVZ) (FSS Ch. 9 §2.4.1.4). In addition and on all ships, a fire detection section covering a ro-ro space is to be separated from (FSS Ch. 9 §2.4.1.2):

- Control station
- Service spaces
- Accommodation spaces

For practical purposes, this means that ro-ro spaces are to be provided with dedicated fire detection sections, since ro-ro spaces generally are located in a dedicated Main Horizontal Zone. Only machinery spaces other than category A located in the same horizontal zone could be covered by the same detection section.

In addition, in case the fixed fire extinguishing system is a manual deluge system, automatic deluge system or pre-action system, MSC.1/Circ.1430 requires that fire detection sections be the same as the zones of the fixed fire-extinguishing system: "*The area of coverage of the detection system sections should correspond to the area of coverage of the extinguishing system sections.*"

MSC.1/Circ.1615 further proposes it on newbuildings with a fixed water-based deluge system:

> "2.1.2 If a fixed water-based deluge system is used for ro-ro spaces and special category spaces then a fire detection and alarm system addressable to the same sections of the deluge systems should be arranged."

For practical purposes, on addressable fire detection and fire alarm systems, several sections may be arranged in series on the same electrical cable and separated by suitably located isolators.

9.2.2.2.6 Monitoring and control

As a minimum, monitoring and/or control are to be available at the following locations:

- At the safety centre (control panel)
- At the navigation bridge (indicating unit capable of identifying which detector has been activated)

- Maintenance planning

[7] Other fixed fire extinguishing systems are wet pipe systems which include their own thermo-sensitive bulbs and will therefore not rely on a separate fixed fire detection system for activation.

Monitoring and control requirements are summarized in the Table 9, in line with FSS Ch. 9 §2.5.1 and SOLAS II-2/7.9.2 & 7.9.3 requirements.

Clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections [FSS Ch. 9 §2.5.1.4]

In addition, MSC.1/Circ.1615 further proposes:

> “2.1.3 In the design of the fire detection alarm system, it should be designed with a system interface which provides logical and unambiguous presentation of the information, to allow a quick and correct understanding and decision-making. In particular, the alarm system section numbering should coincide with the sections of other systems, such as fixed water-based fire-extinguishing system or television surveillance system, if available.”

<u>System operating conditions:</u>

The control panel is to make a clear distinction between:

- Normal condition
- Fire alarm condition
- Acknowledged alarm condition
- Electrical fault condition
- Silenced alarm condition
- The system is to reset automatically to normal operating conditions after all alarms and fault conditions are cleared

Table 9: Monitoring and control requirements according to the different locations (X: Monitoring and control required, Blank cell: Not required)

Monitoring and control		**Control panel (Safety centre)**	**Indicating unit (Navigating bridge)**	**Other indicating unit**
Fire detection	Fire alarm (See [9.2.2.2.3])	X Visual and audible	X Visual and audible	X Visual and audible
	Means to acknowledge fire alarm	X (sounders may be manually silenced)		
	Monitoring and Control for: • Fire doors • Ventilation	X		
	Location of sections and spaces covered	X	X	X
Power supplies and electrical circuits necessary for detection system operation	Electrical fault alarm (distinct from fire alarm): • Single open or power break • Single ground fault • Single wire-to-wire fault	X Visual and audible		
	Means to acknowledge electrical fault alarm	X		

It can be noted that some clarifications about the requirements regarding interrelation between the central control station, navigation bridge and safety centre are provided by MSC.1/Circ.1368[8].

Guidelines on ergonomic criteria for bridge equipment and layout are provided by MSC/Circ.982 but they are more related to improve the reliability and efficiency of navigation.

9.2.2.2.7 Sources of power

9.2.2.2.7.1 Continuous fire detection capability

The fixed fire detection and fire alarm system is to be fed from two sources of power with separate feeders, including an emergency source of power (FSS Code Ch. 9 §2.2.1). An emergency source of power has to comply with the requirements of SOLAS II-1/42 and 42-1 regarding location and

[8] Only applicable for passengers ships (SOLAS II-2/23).

autonomy. Especially, it has to be able to supply the fire detection system for 36 hours, after which it has to be capable of operating the fire alarm for 30min (FSS Ch. 9 §2.2.4). It is either the ship emergency generator (+ transitional source of emergency power) or dedicated accumulator batteries (FSS Ch. 9 §2.2.4 & 2.2.5).

An automatic change-over switch is to be provided to manage the transition between the main and emergency source of power, and a fault should not lead to the loss of both power supplies.

No temporary loss of the fire detection capability due to this change-over switch is accepted. In addition, a transitional battery may be required if the temporary loss of power can damage the fire detection system as per FSS Ch. 9. §2.2.2.

Although the alarm sounder is not formally required to be part of the fire detection system, IACS UI SC35 makes it clear that it is to be powered from a main and emergency source of power and from the transitional source of emergency power where required.

There shall be sufficient power to permit the continued operation of the system with all detectors activated, but not more than 100 if the total exceeds this figure [FSS Ch. 9. §2.2.3].

9.2.2.2.7.2 Consequences of a fault

After an electrical fault or electrical failure:

- Identification capability is to be kept in the whole section, except for the faulty detector (FSS Code Ch. 9 §2.1.6.1, applicable to addressable systems)
- The initial configuration is to be restored (FSS Code Ch. 9 §2.1.6.2, applicable to addressable systems)

9.2.2.2.8 Temporary disconnection

FSS Code Ch. 9 §2.1.1 allows temporary disconnection of the fire detectors in ro-ro spaces during loading and off-loading, provided:

- Detectors in other spaces remain operational
- Fire patrol is maintained in the ro-ro space while the detectors are disconnected
- The detectors are automatically re-connected after a pre-set duration

MCA (UK Flag Administration) clarify in their guidance that:

- Manual call points and manual release mechanisms may not be disconnected
- The duration of the timer is to be adapted to the time of loading/unloading
- The central unit is to indicate whether the detector sections are disconnected or not

9.2.2.3 Sample extraction smoke detection systems

9.2.2.3.1 General

This section describes the performance expected from, and the requirements of, the sample extraction smoke detection systems, as detailed in the standards and regulations, with a particular focus on the system interface.

9.2.2.3.2 General arrangement

The system consists of:

- Sampling pipes with smoke accumulators at their open ends;
- A control panel which includes a viewing chamber or smoke sensing units, capable of detecting smoke if collected in the smoke accumulators.

The system may be combined with a gas fire-extinguishing system, i.e. the sampling pipes may also be used to convey the fire-extinguishing gas to the ro-ro cargo space. In this case, 3-way valves are required in order to properly segregate the smoke analysing function from the gas fixed fire-extinguishing system.

[FSS Code 10.2.1.1]

The control panel shall be located on the navigation bridge or in the fire control station. An indicating unit shall be located on the navigation bridge if the control panel is located in the fire control station.

[FSS Code 10.2.4.1.2]

The control panel shall permit observation of smoke in the individual sampling pipes.

[FSS Code 10.2.2.3]

The system is to be capable either of continuous operation or of scanning at regular intervals (with a maximum scanning interval defined in FSS Code 10.2.1.2)

[FSS Code 10.2.1.2]

9.2.2.3.3 Alarm

A visual and audible alarm is to be activated on the bridge and at the control panel (see §9.2.2.3.2) in case of smoke detection. The alarm on the bridge is not required to provide any indication on the location where smoke has been detected. It is expected that the crew can then determine at the smoke sensing unit which cargo hold is on fire and operate the pertinent three-way valve for discharge of the extinguishing agent.

[FSS Code 10.2.1.1.4, 10.2.4.1.1]

9.2.2.3.4 Space identification

Attention is paid to proper identification of the spaces where smoke may be detected. This first works through the arrangement of sampling pipes and associated smoke accumulators: smoke accumulators from more than one enclosed space are not to be connected to a given sampling pipe and, more generally, the sampling pipe arrangement is to ensure that the location where smoke is present can be readily identified.

[FSS Code 10.2.3.1.5, 10.2.3.2.1]

In addition, maps or equivalent information is to be displayed close to the control panel or repeater units in order to allow proper identification of the space where smoke has been detected.

[FSS Code 10.2.4.1.3]

9.2.2.3.5 Electrical arrangement

9.2.2.3.5.1 Power supply

Any loss of power for the system is to initiate a dedicated visual and audible alarm at the navigation bridge and an alternative power supply is required for the system.

[FSS Code 10.2.1.6, 10.2.4.1.4]

9.2.2.3.5.2 Alarm or fault conditions

In case of smoke detection alarm or fault conditions:

- Clear distinction is required between normal, alarm, fault and silenced conditions

- It is to be possible to acknowledge all alarm and fault signals from the control panel and it is allowed to silence the audible alarms
- The system is to reset automatically to normal operating conditions after alarm and fault conditions are cleared

[FSS Code 10.2.4.1.5, 10.2.4.1.6]

9.2.2.4 Video monitoring

FSS Code 9.2.1.2.4.9 indicated that the fire detection system may be arranged with output signals to closed circuit television (CCTV) systems.

Further, MSC.1/Circ.1615 states that:

> ”2.2.1 Television surveillance systems can be effective for rapid confirmation of a fire after activation of fire alarms, as well as rapid execution of related actions after the confirmation of fire. This supports the activation of the correct deluge section, as well as manual fire-fighting.
>
> 2.2.2 Effective television surveillance systems should be provided in ro-ro and special category spaces for continuous video monitoring of these spaces and be provided with immediate playback capability to allow for quick identification of fire location, as far as practicable. Continuous monitoring of the video image by the crew needs not be ensured.”

9.3 Operational aspects

The bridge alarm fire panels are the key point of administrating fire detectors and the fire alarm system, as well as relaying information back to the officers in charge. In a critical situation the IAMCS thus plays a key role in creating overview of the situation and thereby also in how well the situation is handled and played out having possible impact on both human lives and material damage.

A bridge fire panel has to successfully integrate all fire detectors in the same panel, it must be reliable, class approved, easy to operate and give the crew an easily accessible overview of which detectors have activated.

The IAMCS are considered easy to operate by the crew, when manuals or thorough introduction is not needed before the crew can start operating the system. Also, in a good system it is not easy to set off or disable any alarms un-intentionally, and the system will not give the operator this impression when being used.

Three fundamental types of alarms can be given in the fire panel systems: False alarms due to a fault in the wiring or the system itself, true alarms, and alarms from false sources, which describes the system reacting correctly but to something that is not a critical occurrence. Examples of the latter could be someone smoking in a cabin, steam from a shower or a sensor getting dirty with saltwater spray.

Of the three alarm types, only the true alarms are desirable, however, alarms from false sources are, in reality, not possible to avoid completely. But, if the AIMCS can show the crew the location and temperature of the detector reacting to the false source, many of these can be explained through logic. This does not mean that they should not be investigated or taken seriously, but it will possibly reduce the stress for the responsible OOW, thereby make him more alert if a true alarm should occur. Some alarms from false sources can be avoided by choosing the optimal type of detector for an optimal location, this is however decided in the design phase of the ship but is in some cases changed afterward.

The false alarms are of course undesirable, and the perfect bridge fire panel would not have such.

Acknowledging the alarms falls into the same three categories. False alarms need to be acknowledged to not bring a non-critical situation to an unwanted level of attention. However, too many false alarms can result in a habit of acknowledging the alarms without taking them serious enough and the fine line of the OOW between being alert when necessary and the fact that a person cannot be alert for long periods of time can be lost.

For the alarms from false sources, the acknowledgement is less likely to tip this afore mentioned balance, since it is also a test of the system and proves that the fire detection is working.

For alarms signalling the real danger it is important that the general alarm is sounded. But it is also important to be able to stop both general alarm and the alarms from the fire panel when everybody is aware of the situation.

If the AIMCS keep producing alarms that needs to be acknowledged the system will be an added stress-factor to an already stressful situation. This is a known problem on board the vessels and it must be stressed that a good bridge alarm panel design takes this into account. It was experienced in the case of the fire on board Pearl of Scandinavia in 2010 that the escalating amount of triggered fire detectors simply jammed the AIMCS so that no valuable information could be provided after the first alarms. See Ref.[2], excerpt below:

"The heavy smoke caused by the plastic pipes loaded on one of the trailers very quickly spread to the entire car deck resulting in all fire detectors being activated. Due to the amount of alarms, the fixed fire detection system jammed, and the detection of the continuing fire aft of the flooding control door was obstructed in this jam."

This is an example of possible useful tool becoming a stress factor.

Bridge fire panels should clearly communicate which fire zone an activated fire detector is located in.

It is in the everyday use of the bridge fire alarm panel also important that it is possible to deactivate loops of fire detectors so that in case of e.g. hot works in a section of the ship, unnecessary alarms can be avoided. In these cases, other measures of fire detection are established by the crew.

The loops that can be deactivated should respond to these fire zones, both for creating a simple overview and to keep the zones small, so that when a zone needs to be deactivated, the whole decks or sometimes more than one cargo deck will not be deactivated and left without fire detection while hot work or other is going on.

Some systems use 2D modelling of the ship structure to visually display where alarms are activated. Others use lamps on a display panels and again some output as an abbreviation or short text that indicates where the sensor is located on a nearby chart. It is important that solutions for display is not easy to misinterpret and is well integrated with the rest of the system, so that a consistent user interface is provided.

examples of on board bridge fire panels currently used in the DFDS fleet are illustrated on Figure 3, Figure 4 and Figure 5. Other systems are used as well, as there is no company standard besides that the systems must fullfill IMO regulations and class standards.

Figure 3. Tyco Minerva T2000 system

Figure 4. Salwico Fire detection system, SG9812_FDS_RF

Figure 5. Fire detection indicator

9.4 Design and production aspects

A new fire alarm panel should have an intuitive user interface and easily provide the wanted response to operator inputs. Bridge alarm fire panels are notoriously known to be hard to navigate due to a bad user interface and very little intuition in the systems. This is a nuisance for those who must handle them on daily basis, thus resulting in non-optimal usage of the fire detection system on board. In a critical situation it can result in limited overview and thus be unsupportive to the crew handling an already stressful situation. Worst case this can lead to wrongly based decisions in a dangerous situation. The IAMCS should therefore aim to provide overview and add valuable information to the crew, with simple and easy to use measures. See Ref.[1], excerpt below:

> *"Firefighting is not the primary function of the crewmembers and actual emergency situations are rare. This means that for most crewmembers such a situation is a once-in-a-lifetime experience. Therefore, seafarers cannot be expected to hold a level of experience equal to that of 'professional firefighters'. These conditions place additional strain on the firefighting preparedness on board ships and need to be carefully considered when designing equipment and work procedures to be used in an emergency situation. Procedures, checklists and decision support systems alone cannot ensure a successful outcome of an emergency situation. Procedures are static tools, whereas emergency situations are dynamic and unpredictable. Many procedures, emergency procedures in particular, bear an inherent assumption that the crew has extensive knowledge of the situation or is able to quickly gain such knowledge, which they in most cases are not. Safety management procedures address a variety of topics besides safety. Often a safety procedure will also contain items relating to insurance issues, internal documentation, general company policies, ordering information, etc., which has no relevance to the crew in an emergency situation."*

The reason for the unfriendly user interface not being developed further yet, might be due to the fact, that the user and the purchaser of the system is not the same and most likely in little or no contact with each other. This makes systems compete on other parameters than interface.

If the systems currently placed on board ships are compared to user interfaces found on private IT-products on shore some would say that the user interface are lacking 15-30 years behind. That means that the knowledge and technology is existing, but it is not applied on board the vessels. To close this gap, would be beneficial to the crew operating the panel. Especially if, when building a new user interface, currently existing and widely applied ways to architect user interfaces would be consulted, so that a certain level of recognition and familiarity from already widely known systems would benefit the fire panel operator.

To improve user interface, it is important, but not limited, to investigate the following issues:

- Some AIMCS systems have the problem, that when first an alarm is activated, as the situation develops other alarms will follow. An escalation of alarms on the panel will make actual use of the panel very hard to operate. It is however still important to relay the information if a fire is spreading, but this should be done in a way where the overview is not lost to the operator of the fire panel. There have been incidents where escalating alarms are due to a jammed AIMCS system, this should be avoided as it is a system error. However, the problem of different fire detectors activating as a fire is spreading is a problem that cannot be avoided by the system, and the information should be given in a way that is not stressful.
- A clear visual overview of the activated fire detectors needs to be well-integrated into the IAMCS. It must be intuitive to read and not possible to misunderstand.

- More intuitive operation of system, so that manuals are only needed for very specific or rare occasions.
- A clear communication to the user of what the next action taken on the system will result in, and when it is done how to undo it if needed. The problem is that some operators will hesitate to explore the fire panel, in fear of triggering an alarm, or shutting down part of the system without wanting to. If the fire panel can inspire the user with more confidence when navigating menus etc. the user is more likely to get familiarized with the system, and thereby a higher level of overview and operational skill set is acquired.
- Clear visual communication of placement of detectors. If not on the panel itself then another solution next to (this also exists in some systems).
- If touch screens are considered in a new user interface design, it is important that it is not possible to unintentionally push buttons or take actions.

9.5 Proposal for development and restrictions

In general, when developing new systems for emergency situations to be applied on board, it is of *huge importance* that the systems can operate without the crew needing to be highly educated in the systems. In general a feedback from the crew on board the vessels are that too many systems are too complicated, considering the many different systems and skillsets required of the crew on board, it is not reasonable to demand that he or she is an expert in all of them at once. When adding the stress of an emergency situation on top of this, simplicity is a valuable asset for a system that needs to be handled in an emergency situation. See Ref. [1].

For further development of the IAMCS some of the following could be interesting to consider:

- Temperature readings directly on the panel, provides important information, some systems already facilitate this.
- When loops of fire sensors are deactivated for some practical reason, a notification that all sensors are not up and running might be useful to automatically have the system generate or to make the system automatically switch on deactivated detectors again after a certain timespan. These options are important to consider, but as *no* extra alarms are wanted it is an intricate matter.
- To show the right information and the right amount of information at a given time is essential for making a good bridge fire alarm panel. Some systems do not provide the operator with the information of what type of sensor is activated some do, to find the right level of detail or the option of easily seeking out more detailed information should be explored.
- Connection to CCTV system. This could add to the already existing fire detecting system, while utilizing equipment already on board. It is however important to stress that many ships do not have mandatory CCTV systems, and if standards and requirements are too harsh, what they have might be taken down to avoid the hassle of compliance. This would be a great loss to safety and a problem for the crew when fulfilling the everyday work tasks.
- Beeper or mobile phone could be connected to alert the OOW when the ship is berthed with no watch on the bridge or in the CCR. This of course only applies to those alarms that do not directly activate the general alarm.
- Possible integration of digital stowage plan. If the location of the different cargo types placement in cargo hold could be shown on request in the fire panel a digitized visual plan of possible dangers of a spreading fire could be highlighted and easy to keep track of. This could help the crew to direct the firefighting resources more efficiently and hopefully minimize damages to both people, ship and cargo. This however requires that a digitized stowage plan

exists, which is not the case for most companies as it is now. However, with further developing of drone technologies there is an intention to be able to automatically be able to automatically generate this kind of information in DFDS in the near future.

- For further development of the AIMCS, it could be interesting to have the system also propose an intelligent first line of actions. For this to be an actual help it is important that it is easy to understand the suggestion, that no paperwork or tables need to be consulted. It is also important that the system can adapt the first line of attack to the situation at hand. If this is in fact possible to a satisfactory level of competency would be interesting to learn. It is important for such a system to avoid that the OOW feels his/her authority limited to follow the suggested action plan or that the OOW takes the situation less serious than if no suggestions would be made. If the system in the future could provide suggestions to such first steps, it also opens up for an interesting discussion of responsibility. Where it is important to keep clear who is in charge and who is advising and what a bad advice from the system would result in.
- Language barriers needs to be considered. The crews are often international, and even as English is often a preferred official working language on board it is not the native language of most crew and the skill to speak, read and write it varies greatly. This needs to be considered both when choosing how the AIMCS should relay information but also in how manuals are constructed.
- Listing of equipment on board could be integrated into the AIMCS, this could have several useful functions. One is to help keeping track of maintenance and expiry dates of the equipment thereby assisting the safety officer on board. A spin-off effect of this is, that if the tool proves useful, then the safety officer is given good incentive to get very well familiarized with the AIMCS on board. Second is to give the crew a quick overview of where the nearest fire extinguisher or other is located in a case of emergency. This could provide useful both for firefighting teams and for the person to make the first inspection of a critical situation.
- An easy way to mute the alarm system if alarms keep ringing in. This should, if possible, be without giving this mute option when no crisis is occurring, to prevent disconnection of the system. The lack of a way to silence the AIMCS has been a problem in previous critical situations. See Ref. [3] and [4]. However, a way to test both the muting and a lot of incoming alarms might be an idea.

Excerpt from Ref [3]:

"Throughout the entire course of events, the bridge team was disturbed and highly stressed by the sound of countless fire alarms, which made it extremely difficult to concentrate.
Even though the alarms were acknowledged continuously on the bridge, it was not possible to keep up paying attention to the incoming alarms.
Because of the very high pace of incoming alarms and the distracting noise, there was a desire to be able to switch off the alarm sounders for the sake of effective communication and not being unduly stressed. But there was no such possibility. For a period, a crewmember was engaged in acknowledging fire alarms only to stop the sound without being able to reflect on any other possible alarms."

Excerpt from Ref [4]:

"Because of the very high pace of incoming alarms and the distracting noise, there was a desire to be able to switch off the alarm sounders for the sake of effective communication and not being unduly stressed. But there was no such possibility. It takes manpower and concentration to operate and acknowledge alarms, and in this case the multiple alarms were a distraction more than an aid to officers and crew. It illustrates that the design feature of the monitoring

and alarm systems that perform well in normal situations is not necessarily a help when handling a complex emergency situation – to some degree quite the contrary. Although it was not the case in these events, it may limit the crewmembers' cognitive capabilities and the prioritizing necessary for handling an emergency situation."

9.6 Conclusion

Many possibilities for developing the current bridge fire panel solutions exists with today's technologies. Simplicity of operation, reliability and providing a good overview with the right level of information is thus some of the important main features that should be prioritized when designing them. Integration of current or new solutions could be a way forward to obtain this.

10 Efficient extinguishing system activation and inherently safe design - Action 7-B

Main author of the chapter: Sif Lundsvig, DFDS

This chapter relates to the action challenge of efficient extinguishing system activation and inherently safe design requirements definition. The chapter aims to describe the relevant rule and regulation requirements as well as current practice on board and what issues this practice brings. Finally, the report highlights future ideas and areas for improvements. Except the Regulation review section, this chapter is written from an operator perspective of Ro-ro and Ro-pax vessels.

Two topics have been considered, one being efficient extinguishing system activation, while the other being the safety and design requirements associated with this. Going forward the term ”system” will be used in short for ”fire extinguishing system”. This term refers to the fixed fire extinguishers located on board a vessel.

The observations are based on interviews and ship visits performed by Lena Brandt, maritime incident reports, as well as input from Wallenius representing the vehicle carrier operators

10.1 Short Description of the addressed Action

The objective of the Action 7-B is to develop guidelines for efficient extinguishing system activation and inherently safe design, through the following tasks:

- Definition of conditions for efficient extinguishing system activation
- Development of design and procedures for extinguishing system activation
- Realistic training and implementation of activation routines and design guidelines

10.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 7-B, i.e. “efficient extinguishing system activation and inherently safe design”. Several kinds of fixed fire-extinguishing systems may be installed in vehicle and ro-ro spaces (see Chapter 0), depending on the type of ship and type of space concerned, with different requirements associated to their activation. A significant focus is put here on the water-based fixed fire-extinguishing systems because they are the most common, and, for practical purposes, the only allowed solution on passenger ships.

It is also to be noted that the design of the fixed fire detection and fire alarm system as a support for decision-making is not covered in detail here, as it is addressed in Chapter 0.

10.2.1 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

Table 10: List of documents used for the review of regulations for [Objet]

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
	MSC.1/Circ.1430/Rev.1, Revised guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces
	IMO FSS Code, as amended
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2020
Flag Administration Rules	Chinese rules for domestic passenger ships, as indicated in IMO SSE5/INF6

10.2.2 Requirements

10.2.2.1 General

SOLAS II-2/20.6.1 [5] requires a fixed fire-extinguishing system to be provided in every vehicle or ro-ro space. It is to be noted that this requirement does not apply to weather decks intended for the carriage of vehicles, because weather decks are not ”spaces”.

Pure cargo vehicle or ro-ro spaces capable of being sealed from outside may be provided with:

- Fixed gas fire-extinguishing system – typically CO_2; or
- Fixed high expansion foam fire-extinguishing system; or
- Fixed water-based fire-extinguishing system – “drencher” type or equivalent.

In the case of special category spaces (i.e. passengers have access to the garage) or if the space cannot be sealed, only the fixed water-based fire-extinguishing system is allowed.

[SOLAS II-2/20.6.1.1 and II-2/20.6.1.2]

It can be noted that China requires CO_2 fixed fire extinguishing system in ro-ro spaces of domestic ferries, whereas such systems are usually avoided in spaces where passengers can have access.

[IMO SSE 5/INF.6]

[IMO FSS Code Ch 5 §2.2.1.2]

10.2.2.2 CO_2 systems

A CO_2 fixed fire-extinguishing system, if installed for the protection of a ro-ro or vehicle space, is to comply with the requirements of IMO FSS Code Ch.5 [9]. Basically, these rules are aimed at ensuring both the efficiency of the system for fire-extinguishing (i.e. effectively inerting the volume to be protected) and avoiding the risk of asphyxiation.

10.2.2.2.1 Requirements for controls and system activation

Especially, precautions are taken in order to avoid inadvertent release into the space:

- Two separate controls are required for releasing the CO_2, meaning two successive deliberate actions;
- It should not be possible to operate the controls in the wrong order;

- Operation of these controls is to activate an audible and visual alarm in the space, which will signal to anybody remaining in the space that CO_2 will be released and that they should leave immediately. The alarm is to remain active for a period long enough to allow evacuation of the space prior to CO_2 discharge; and
- Both controls are to be enclosed in a box in order to avoid unintended operation.

[IMO FSS Code Ch 5 §2.2.2 & §2.1.3.3]

As a note, automatic release of CO_2 systems is normally not allowed – again in order to avoid asphyxiating people.

[IMO FSS Code Ch 5 §2.1.3.4]

The manual controls for the release of the CO_2 into the protected space are to "be readily accessible, simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there shall be clear instructions relating to the operation of the system having regard to the safety of personnel."

[IMO FSS Code Ch 5 §2.1.3.3]

10.2.2.2.2 History

IMO FSS Code Ch 5 has been fully revised by IMO Resolution MSC.206(81) which entered into force on 01/07/2010. However, the requirements related to the release of CO_2 systems have been quite consistent over time – with two continued concerns: efficient release and avoiding asphyxiating people. One major evolution with MSC.206(81) was the introduction of the requirement for two separate controls, meaning two effective actions for releasing the CO_2.

10.2.2.3 High expansion foam systems

A high expansion foam fixed fire-extinguishing system, if installed for the protection of a ro-ro or vehicle space, is to comply with the requirements of IMO FSS Code Ch.6 [9].

10.2.2.3.1 Requirements for controls and system activation

Here again, it is taken into account that high expansion foam flooding can be very hazardous if people are trapped in the space and an automatic pre-discharge alarm is required prior to foam release.

[IMO FSS Code Ch 6 §3.1.20]

In addition, breathing apparatuses are foreseen for fire-fighters who would need to enter the space after foam release.

[IMO FSS Code Ch 6 §3.1.15]

Then requirements for the release controls aim at ensuring efficient and quick release of the system:

- Means of controls are to be "readily accessible and simple to operate, and […] arranged at positions outside the protected space not likely to be cut off by a fire in the protected space"; and

[IMO FSS Code Ch 6 §3.1.12]

- Operating instructions and plans showing the sections covered by the system are required close to the operating positions.

[IMO FSS Code Ch 6 §3.1.8 & 3.1.16]

Manual release of high expansion foam systems is required. Most are capable of manual release only. But automatic release may however be allowed, without further requirement for ro-ro and vehicle spaces.

[IMO FSS Code Ch 6 §3.1.1]

10.2.2.3.2 History

IMO FSS Code Ch 6 has been fully revised by IMO Resolution MSC.327(90) which entered into force on 01/01/2014. Prior to this date the requirements related to the controls and activation of high expansion foam systems were very scarce and for practical purposes limited to:

"The […] means of controlling the system shall be readily accessible and simple to operate and shall be grouped in as few locations as possible at positions not likely to be cut off by a fire in the protected space."

10.2.2.4 Water-based systems

Water-based fixed fire-extinguishing systems installed for the protection of ro-ro, vehicle or special category spaces are to comply with the requirements of IMO MSC.1/Circ.1430 rev.1 [10]. This guideline contains a number of requirements regarding the dimensioning and design of the system and also covers its controls, with a view to ensure efficient and easy operation of the system.

10.2.2.4.1 Requirements for controls and system activation – Section valves

Water-based fixed fire-extinguishing systems installed for the protection of ro-ro, vehicle or special category spaces are divided into sections, i.e. the activation of the system will not lead to releasing water over the whole space, only over a section of the space. A section physically corresponds to a grouping of pipes and nozzles covering a given area of the space and that can be isolated from the rest of the system by a section valve.

[MSC.1/Circ.1430 rev.1 §3.2]

Operation of the section valves may be local or remote and "means should be provided to prevent the operation of the section control valves by an unauthorized person".

[MSC.1/Circ.1430 rev.1 §3.2.1]

The section valves are to be easily accessible, outside of the protected space and their location is to be "clearly and permanently indicated". In addition, ventilation is required at the section valve locations in order to avoid smoke accumulation.

[MSC.1/Circ.1430 rev.1 §3.2 and §3.2.1]

It is to be noted that there is no requirement to gather all section valves at the same location – as was initially the case in traditional drencher systems covered by IMO Resolution A.123(V). However, for deluge systems, i.e. systems for which effective activation requires opening the section valves, the controls of the section valves, together with an indication of their position and the controls for the pump, are to be grouped in a continuously manned control station[9].

[9] SOLAS II-2/3.17 and II-2/3.18 [3]: "Continuously manned central control station" is a central control station which is continuously manned by a responsible member of the crew and "Control stations" are those spaces in which the ship's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire control equipment is centralized. Spaces where the fire recording or fire control equipment is centralized are also considered to be a "fire control station".

[MSC.1/Circ.1430 rev.1 §3.2.2]

10.2.2.4.2 Requirements for proper system operation

As a complement, a number of requirements cares for the easy and informed operation of the system:

- Operating instructions are to be displayed at operating positions, in the working language of the ship; and

[MSC.1/Circ.1430 rev.1 §3.14 & §3.18]

- A list or plan showing the areas covered by each section is to be displayed on board.

[MSC.1/Circ.1430 rev.1 §3.15]

For passenger ships, IMO Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships [11] focusses on the easy identification of the section to be activated, recommending:

- That the sections of the water-based fixed-fire extinguishing system correspond with the sections of the fixed fire detection and alarm system in order to ease decision making and to avoid erroneous activation; and

[MSC.1/Circ.1615 §2.1.2 and 2.1.3]

- Visual marking of the sections in the ro-ro, vehicle or special category space.

[MSC.1/Circ.1615 §2.6]

10.2.2.4.3 Requirements for automatic activation

IMO MSC.1/Circ.1430 rev.1 [10] allows and provides requirements for automatic activation of the system. This is a recent evolution which was introduced in IMO MSC.1/Circ.1430 – only manual activation was allowed before.

[MSC.1/Circ.1430 rev.1 §3.1]

In case of automatic activation:

- A warning notice is to be displayed at the accesses to the space, mentioning the possibility of automatic water release; and

[MSC.1/Circ.1430 rev.1 §3.17]

- A visual and audible alarm is to be triggered at a continuously manned control station, indicating the activated section.

[MSC.1/Circ.1430 rev.1 §3.5]

There are two technical options for automatic activation:

- Automatic sprinkler nozzles with normally wet pipes and thermosensitive bulbs that will break open in case of high temperature detection; or
- Open nozzles with normally dry pipes, controlled by section valves that will open automatically upon fire detection by the fixed fire alarm and fire detection system. In this case:
    - The fixed fire detection and fire alarm system is to involve two types of fire detectors (heat/flame/smoke). TV monitoring of the space is also required for performance-based systems, i.e. systems that have been approved based on a fire test rather than on a standard flow-rate;

[MSC.1/Circ.1430 rev.1 §4.8.2, §5.6.1 and §5.6.2]

- An alarm is required in case of activation of any single fire detector and the system is to discharge water in case of activation of two or more detectors. For performance-based systems, release upon activation of one detector may be accepted;

[MSC.1/Circ.1430 rev.1 §4.8.3 and §5.6.3]

- Means for manual release and stop of the system are also required. Automatic release may be disconnected during on- and off-loading operations, then automatically reconnected; and

[MSC.1/Circ.1430 rev.1 §4.8.4 and §5.6.3]

- Simultaneous release of multiple sections is to be avoided (explicitly required for prescriptive-based systems, i.e. systems with standard flowrate, as opposed to performance-based systems).

[MSC.1/Circ.1430 rev.1 §4.8.4]

10.2.2.4.4 History

Requirements for water-based fixed fire-extinguishing systems installed in ro-ro, vehicle or special category spaces have evolved a lot over time. Table 11 gives a short summary of the applicable IMO regulations in this respect. Key evolutions with respect to activation and control of the systems are:

- MSC.1/Circ.914 allows automatic release; and
- MSC.1/Circ.1430 also allows automatic release and includes clear requirements for grouped, remote control of the system from a central control station / wheelhouse rather than direct, mechanical control from the “drencher room” as required by IMO Resolution A.123(V) for traditional drencher systems.

Table 11: Summary of regulation changes

Regulation change	Date	Title	Summary
Resolution A.123(V)	25/10/1967	Recommendation on fixed fire extinguishing systems for special category spaces	Covers the traditional "drencher" systems Superseded by MSC.1/Circ.1430
MSC/Circ.914	04/06/1999	Guidelines for the approval of alternative fixed water-based fire-fighting systems for special category spaces	Allows alternative water-mist systems and an option for automatic release. Superseded by MSC.1/Circ.1272
MSC.1/Circ.1272	04/06/2008	Guidelines for the approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces equivalent to that referred to in resolution a.123(V)	Supersedes MSC/Circ.914 Superseded by MSC.1/Circ.1430
MSC.1/Circ.1430	31/05/2012	Revised guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces	Supersedes MSC.1/Circ.1272 and A.123(V) Amended by MSC.1/Circ.1430/Rev.1
MSC.1/Circ.1430/Rev.1	07/12/2018	Revised guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces	Amends MSC.1/Circ.1430

10.3 Operational aspects

Three main types of fixed fire extinguishing systems exist on board vessels. These three are typically drenchers, foam and inert gas systems. On DFDS vessels are used drencher systems and inert gas systems. Activating a fixed fire extinguishing system is the captain's decision.

On vessels managed by Wallenius Marine, as well as on the majority of the world fleet of vehicle carriers, CO_2 fixed firefighting systems are installed on all vessels for use in both engine rooms and cargo hold.

10.3.1 Inert gas systems

10.3.1.1 Ro-ro and ro-pax vessels

Typically, this system is used in the engine room and engine control room as these rooms are packed with electrical devices and other equipment that will be destroyed by use of water. For the inert gas systems to work efficiently the room needs to be locked airtight. For safety reasons a room must be vacated before inert gasses are released, as the oxygen is repressed from the room. These two important factors often slow down the speed and/or efficiency with which the system can be activated. However, since LASH FIRE mainly focuses on the cargo holds, the description of how inert gasses are used on board will be kept brief.

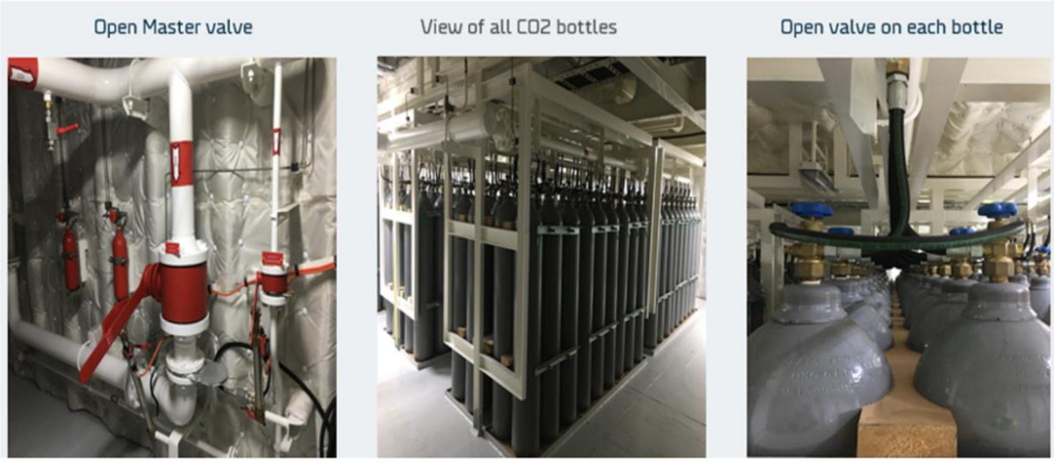


Figure 6. Inert gas system (High pressure CO2) for use in the Engine room on a ro-rax ferry.

10.3.1.2   Vehicle carriers

On vehicle carriers, a CO_2 low pressure fixed firefighting system is the most common type and is used in both engine rooms, cargo holds and other spaces requiring fixed firefighting systems, with exception of galleys. Due to the big volumes of the cargo holds, low pressure systems with liquefied CO2 is the type being used. The insulated tank (or tanks) and its cooling compressors, valves and release mechanisms are typically located in a dedicated CO_2-room on upper deck, classified as a Control station. A second duplicated remote release station is located in a separate Fire control room.

Figure 2. CO2 tanks in a vehcile carrier.

Figure 2. Example of CO2 release cabinets in CO2-room.

Figure 3. Pneumatically operated CO2-section valve.

Due to safety reasons the use of CO_2 is connected with rigid precautions to ensure that no persons are left in or near the space in question upon the release. Any first responder or manual fire fighting operations must be aborted and the crew must be ~~mustered~~ evacuated and reported safe before the release of CO_2 can take place. The time frame for alarm, on site confirmation, situation assessment, first responder and fire fighting group mobilization is ideally about 20 minutes. Experience however show that the CO_2 release in actual cargo hold fires would take about 20-30 minutes.

The release operation in itself, once the decision has been taken, is usually not time consuming and is done as a series of manual and automated steps as described in the release instruction posted in the release station. However, preparedness for the operator with a good knowledge of the system, good instructions and clear markings of valves and equipment, are important for a successful and quick release of CO_2 since the system is technically complicated. As shown in the example in Figure 4, the time for the actual activation of CO_2 would take a few minutes until the release of gas starts. The release time of the total required amount of CO_2, typically 30-50 tonnes, to the largest space is in the region of 15 minutes.

As can be judged from the above description the efficient release of CO_2 is more dependent on the confirmation of fire, situation awareness, safety precautions and correct decision-making than of the system and the actual release operation.

RELEASE FROM SAFETY CONTROL ROOM
RELEASE TO ENGINE ROOM AND
ZONES.

1. TAKE THE UNDERGLASS KEY.
2. OPEN DOOR TO REMOTE RELEASE BOX FOR AREA IN QUESTION. (ACTIVATES ALARM AND VENT. STOP).
3. CHECK THAT EVERYBODY HAS LEFT THE ROOM.
4. STOP FUEL PUMPS. CLOSE FUEL VALVES AND ALL OPENINGS. (ENGINE ROOM ONLY)
5. OPEN DOOR TO BOX FOR MASTER CYLINDERS.
6. OPEN SCREW VALVE ON ONE OF THE MASTER CYLINDERS.
7. OPEN MASTER CONTROL VALVE NO. 1, IN RELEASE BOX. AFTER TIME DELAY (APPR. 30–40 SEC.) THE MAIN VALVE WILL OPEN (4).
8. OPEN MASTER CONTROL VALVE NO. 2, IN RELEASE BOX. THE 5" MAIN VALVE (4) WILL CLOSE AUTOMATICALLY AFTER CALCULATED RELEASE TIME. (2 MIN FOR E/R AND 15 MIN. FOR HOLDS)
9. CHECK THE CO2 QUANTITY BY THE CO2 LIQUID CONTENTS METER. IF MORE CO2 IS REQUIRED, PRESS BUTTON "CO2 RE–RELEASE" (49).

RELEASE FROM CO2 ROOM
RELEASE TO ENGINE ROOM AND ZONES.

1. TAKE THE UNDERGLASS KEY.
2. UNLOCK THE PADLOCK FOR "PILOT VALVE FOR ENGINE ROOM" (16). OPEN THE DOOR AND OPEN THE PILOT VALVE FOR AREA IN QUESTION.
3. CHECK THAT EVERYBODY HAS LEFT THE ROOM.
4. STOP FUEL PUMPS. CLOSE FUEL VALVES AND ALL OPENINGS.
5. UNLOCK THE PADLOCK FOR "PILOT VALVE FOR MAIN VALVE" (16A). THE MAIN VALVE WILL CLOSE AUTOMATICALLY AFTER CALCULATED RELEASE TIME.
6. CHECK THE CO2 QUANTITY BY MEANS OF THE CO2 LIQUID CONTENTS METER. ADDING MORE CO2 PRESS BUTTON "CO2 RE–RELEASE" (49).

PROTECTED SPACE	CO2 QUANTITY	RELEASE TIME
ENGINE ROOM	8950 KGS	2 MIN

EMERGENCY RELEASE FROM CO2 ROOM
RELEASE TO ENGINE ROOM
AND ZONES.

1. CHECK THAT EVERYBODY HAS LEFT THE ROOM.
2. CLOSE ALL OPENINGS.
3. CLOSE PILOT PRESSURE VALVE (13)
4. ACTIVATE RELIEF VALVE FOR PILOT SYSTEM (19).
5. REMOVE THE YELLOW PLASTIC COVER ON THE PNEUMATIC ACTUATOR.
6. MANUAL OPENING OF VALVE FOR THE GROUP IN QUESTION BY MEANS OF THE HANDLE. (ACTIVATES ALARM AND VENT. STOP).
7. MANUAL OPENING OF THE MAIN VALVE BY MEANS OF THE HANDLE.
8. MANUAL CLOSING OF THE MAIN VALVE AFTER THE CALCULATED RELEASE TIME.
9. MANUAL CLOSING OF THE VALVE FOR THE ZONE IN QUESTON.
10. CHECK THE REQUIRED AMOUNT OF CO2 ON THE CO2 LIQUID CONTENTS METER (ACCORDING TO BELOW SCHEME)
11. AT THE FIRST PORT OF CALL, A SERVICE AGENT IS TO BE CALLED.
12. AT THE FIRST PORT OF CALL THE CO2 VESSEL SHOULD BE REFILLED.

Figure 4. A typical CO_2 – Maker's release instructions

10.3.2 Foam system

Fixed foam systems are not installed in the DFDS fleet. Foam is only used on board as manually handled extinguishers in case of oil fires.

Fixed foam systems for Cargo holds is not discussed in this report.

10.3.3 Drencher system

This system uses water to extinguish a fire or limits the spreading of a fire by cooling down surroundings. Less precautions needs to be taken to activate this system than the inert gasses. This does however not imply that activation is not a serious matter, as ships stability can be affected if things go wrong and cargo can be damaged or destroyed.

Figure 7. Active drencher system on a car deck

The drencher systems are typically activated at one of the fire detection-panels, these panels can be found in many different designs by different producers. In the DFDS fleet several different systems can be found on board the vessels, to mention some: Tyco Minerva, Consilium, Autronica Automaster and Salwico. To find an example of how a fire detection panel is operated on Magnolia, see ANNEX D.

When activating the drencher system, the following should be considered:

- Which sections should be activated?
- Do the cargo types in the section allow for water extinguishing? Or is there some type of IMDG good that hinders this action? Reefers?
- Starting the bilge pumps to, make sure to avoid water on deck creating free liquid surfaces and thereby bad stability of the vessel.

10.3.3.1 System activation

Can it be confirmed that the system is activated and working as intended? The section that needs to be activated is determined by feedback from the fire detectors and the person sent to verify the outbreak of fire. Sometimes CCTV can be used as well. On some vessels the section of the detectors registering smoke/flames can be seen directly on the fire panel at the SCS. On other vessels the number of the fire detector can be looked up and the section then found on a drawing showing the sections and numbers of fire detectors, see Figure 8 below. The crew prefers to be able to identify the section that needs activation directly at the fire panel as it saves valuable time.

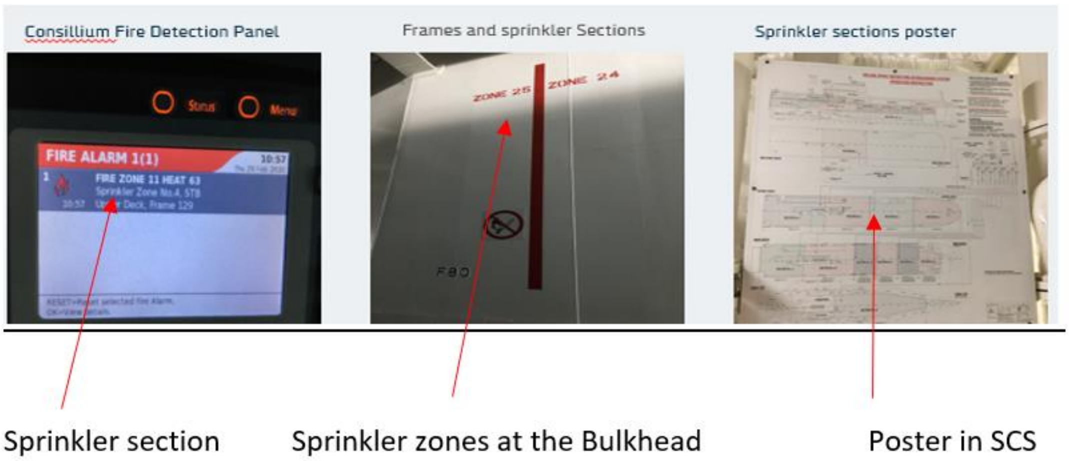


Figure 8. Drencher system- Control panel and markings

10.3.3.2 IMDG

Location of IMDG goods can be found by looking at the cargo stowage plan. This is accessible at the bridge.

10.3.3.3 Bilge pumps

Pumps needs to be started as soon as the drencher system starts pouring water over the deck, this responsibility falls to the engine department, often the chief engineer or the 1st engineer. This is often done from the engine control room or manually. Knowledge of the specific pumps are often needed to perform this task well, as the pumps often are of the type that cannot run dry without breaking down[10]. This means that the rolling movement of the ship poses a challenge to the pumps. Some vessels try to mitigate this, by leading the water from deck into tanks before pumping it overboard. At some vessels, the volume of water that the pump can remove is not well proportioned to the system though. Minimum demands are of course fulfilled, but in some cases the pumps are so powerful that they empty the water reservoirs too quickly risking running dry and then breaking down. Clocking of scuppers or pumps are also a known problem as every smaller loose object on deck will wash to the scuppers when the fire extinguishing system starts.

10.3.4 Main contributors to a quick activation of the fire extinguishing systems

Main contributors to a quick activation of the fire extinguishing systems can be listed as follows:

- Quick confirmation and overview:
  - Fast manual identification of the fire or with the use of CCTV.
  - More than one detector is activated gives an identification of a larger area effected as two detectors are not likely to fault at the same time.
  - Good knowledge of the vessel and how to get around from deck to deck/engine room
  - Quick assessment of IMDG goods or APV's at the relevant section, or in adjacent decks or sections.
- Clear roles:
  - No doubt of line of command, or how to execute the tasks that needs to be carried out
  - No doubt of alarm signals or mustering station

[10] Pumps of this type are typically centrifugal pumps.

  - Culture, some officers will wait for the master's approval and not start action immediately. A remedy for this is to make sure captains standing orders should address especially for night duties regarding first action to extinguish. E.g. if fire is seen please start extinguishing immediately with local equipment or sound out the alarm.
- Fast activation:
  - Trained crew who knows how to activate the fixed fire fighting system
  - Drencher can be started remotely from the bridge
- Timing:
  - During night, the engine room is unmanned, and all crew except night watch are sleeping, therefore it will take longer for the crew to muster
  -

10.3.5 Disadvantages

Draw backs of the three types of fixed fire-fighting systems are as follows:

- Cargo and equipment are damaged or destroyed (foam and water)
- Dangerous to human life (Inert gasses). Delay ~~Hinders~~ immediate release.
- Operation needs continues training of the crew
- Stability of vessel can be influenced if water (or foam) ~~are~~ is not pumped overboard
- Storage of extinguishing remedies (foam and inert gasses)
- System can run short of extinguishing medium (foam and inert gasses)
- Nozzles get clogged with rust flakes if not rinsed frequently (water)
- Wet pipe systems can get frost damages (water)
- Heavy cleaning after use (foam)
- Works only if rooms are sealed air-tight (inert gasses)
- Can be blocked by watertight trailer covers and the like (water and foam)
- Environment and health issues (foam)
- Installation and maintenance costs (all)
- Manual release is often time consuming and demands specialist knowledge (all)

There are always unexpected problems developing when first a critical situation is escalating. The above is therefore the general disadvantages. However, two examples of unexpected problems are given by the fires of Brittania Seaways (2013) and Lisco Gloria (2010).

On Brittannia seaways the Lyngsø fire panel broke down during the fire in 2013, and the crew needed to locate and operate valves etc. to get the fire extinguishing system running. It is important that the crew has knowledge of how to operate the system - but also that there is back-up not relying on electronics. Even though a system operated from the SCS saves a lot of time, it is an advantage to be able to operate the system manually without a huge delay. See [1].

On Lisco Gloria as the cargo started burning the cargo debris where flushed down the scuppers clogging the system draining system. This most likely caused the list of the vessel since the water used for fire extinguishing could not be pumped overboard quickly enough. See [2].

10.4 Design and production aspects

A safe design of a fire extinguishing system should in the best imagined case:

- Be simple to operate
- Start extinguishing immediately after activation
- Be extremely efficient in extinguishing a fire - no matter the size

- Not be possible to release by mistake
- Be able to handle different types of fires (electrical, oil, IMDG goods, APV etc.)
- Be class approved and live up to IMO standards
- Take up little space on the vessel
- Preferable not have the option of running out of extinguishing medium
- Safe for humans and marine environment
- Preserve vessel, cargo, and equipment as much as possible
- Able to reach the fire without delay when activated
- Possible to activate remotely
- Possible to activate if electricity fails
- Not endanger vessel stability
- Easy to maintain or even better - maintenance free
- Easy to include full scale in fire-drills
- Intuitive and simple to understand how they are operated
- Not take up cargo space
- Be reliable and not cause faults and/or delays in activation
- Be easy to clean up after when the fire is extinguished
- Not limit crew access to the section where the system is activated
- Provide easy overview of where the system is activated
- Be easy to shut down again
- Work on weather decks as well as below decks
- Be able to handle ship movements and rough environments

Neither the inert gas system, the foam or the water drenchers does fulfil these requirements - this list represents requirements to the ideal system.

10.5 Environmental aspects

The medium used to extinguish fire should not be harmful to human or marine life. The latter is especially important if the medium is pumped overboard.

10.6 Proposal for development and restrictions

Preferably a new fire extinguishing system - fixed or not - can be used on the complete vessel. The more different systems that needs to be integrated and maintained the bigger the chance of failure, be it due to human errors, mechanical or other. Also, the more systems are on a vessel, the more systems the crew needs to familiarize them self with - and already the many systems with different interfaces plenty. A new system would therefore preferably integrate with the existing ones, or an integrated solution would otherwise be included, at least over time.

It is important that the crew has the control over the activation, so that no unintended activation is done. This is a safety issue both for vessel, cargo and humans on board.

The complete fire extinguishing system must be designed so that it includes both the “active part” being the means of fire extinguishing and the “post treatment” such as pumping media ~~water~~ overboard. The system should be designed so that it is intuitive enough that a lot of training and special know-how of the system and vessel is not needed to handle it. Often bilge pumps arrangements needs a lot of familiarisation before they can be handled correctly without a pump running dry or pumping from a wrong localisation. Capacity and technical demands to the systems are covered by SOLAS, but nowhere are softer values of ease of operation and intuitive systems a demand.

In addition to safe, efficient and robust fixed fire fighting systems, focus should be to provide support systems for efficient means of situation awareness and correct decision making. A combination of tools such as CCTV, temperature sensors and flammable or toxic gas sensors could provide the crew with critical information, preferably monitored in a centralized Fire control station. Detailed plans of the type of cargo and its location is also important for efficient decision making.

11 Firefighting resource management centre - Action 7-C

Main author of the chapter: Sif Lundsvig, DFDS

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 7-C i.e. Firefighting resource management centre requirements definition.

11.1 Short Description of the addressed Action

Action 7-C goal is to develop and validate a firefighting resource management centre (FRMC) with improved design for critical operations in case of fire, reducing the potential for human error, accelerating time sensitive tasks and providing more comprehensive and effective decision support through the following tasks:

- Definition of conditions for firefighting resource management centre
- Development of firefighting resource management centre design
- Drone development and onboard assessment
- Simulator for firefighting resource management centre prototype
- Deployment of firefighting resource management centre prototype and validation tests

11.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 7-C, i.e. “firefighting resource management centre”.

11.2.1 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable to old ships.

A brief summary of the main regulation changes related to Action 7-C is provided in Table 11 with a particular focus on regulations relevant to Action7-C.

Table 12: Summary of regulation changes

Regulation change	Application date	Adoption date	Summary
MSC.24(60)	01/10/1994	10/04/1992	Introduces the notion of central control station and continuously manned central control station
MSC.216(82) – Annex 3	08/12/2006	01/07/2010	Introduces the requirements for a safety centre on board passenger ships

Table 13: List of documents used for the review of regulations for Action 7-C

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
	MSC.1/Circ.1368, Interim clarifications of SOLAS chapter II-2 requirements regarding interrelation between the central control station, navigation bridge and safety centre
	MSC/Circ.982, Guidelines on ergonomic criteria for bridge equipment and layout
	IMO FSS Code, as amended
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
	DNVGL Rules for the Classification of Ships, January 2017
	LR Rules and Regulations for the Classification of Ships, July 2016
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 28/12/17 edition
	US Coast Guard Code of Federal Regulations (CFR) 46, 2019 online edition
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

11.2.2 Onboard procedures

It is to be noted that IMO requirements regarding onboard procedures and actions to adopt in case of fire emergency remain on the general, functional requirement level. The detail of the actions to be actually taken is reckoned to be case-specific and ship-specific, and is therefore left to specific onboard procedures, safety management system, and crew members experience and analysis of the situation. It is generally required that the crew members know the systems, how to use them and how to maintain them:

- SOLAS II-2/15 [5]provides very high-level requirements about the onboard instructions, organisation and training, as well as about the necessary knowledge and skills of crew members.
- IMO ISM Code [38] requires that “every Company should develop, implement and maintain a Safety Management System (SMS) which includes […] instructions and procedures to ensure safe operation of ships and protection of the environment in compliance with relevant international and flag State legislation.” The ISM Code contains one chapter about ‘7 Shipboard operations’ and another about ‘8 Emergency preparedness’ with high-level requirements in this respect.

With respect to the safety centre (see below §11.3.2), IMO MSC.1/Circ.1368 [39] clarifies that the onboard safety management system is to specify the operational hierarchy between the safety centre and the wheelhouse, and requires that attention should be paid to the following aspects when preparing the shipboard safety management system:

- Number of crew available for immediate response to the safety centre in an emergency;
- Definition of the duties of the safety centre personnel and navigation bridge personnel in order to avoid interferences; and

- Emergency procedures are to provide for coordination of emergency management actions and communications.

[MSC.1/Circ.1368 §5]

11.3 Requirements

11.3.1 Central control station

SOLAS [5] requires control and monitoring for a number of safety systems to be gathered in the continuously manned central control station which, for practical purposes, usually coincides with the wheelhouse:

- Fixed fire detection and fire alarm systems and general and fire alarms, including explicitly, for passenger ships carrying more than 36 passengers, alarms and detector status indication;

[SOLAS II-2/7.9, SOLAS II-2/3.9]

- Fire door indicator panels and fire door closure, including explicitly, for passenger ships carrying more than 36 passengers, controls and position indication for remote closing of the fire doors system;

[SOLAS II-2/7.9, SOLAS II-2/9.4.1.1.5, SOLAS II-2/3.9]

- Ventilation fans, including explicitly, for passenger ships carrying more than 36 passengers, status indication and controls for shutting down and reactivating the ventilation fans;

[SOLAS II-2/7.9, SOLAS II-2/3.9]

- Automatic sprinkler, fire detection and fire alarm systems;
- Watertight door indicator panels and watertight door closures;
- Communication systems including telephones; and
- Microphones to public address systems.

[SOLAS II-2/3.9]

11.3.2 Safety centre

11.3.2.1 General

SOLAS II-2/23 [5] has been introduced through MSC.216(82) amendments [41] and applies to passenger ships built on or after July 2010. It specifies that a safety centre is to be provided on board in order to “assist with the management of emergency situations”.

[SOLAS II-2/23.2]

11.3.2.2 Location and manning

The safety centre may “either be a part of the navigation bridge or be located in a separate space adjacent but having direct access, to the navigation bridge”.

[SOLAS II-2/23.3]

When the safety centre is part of the bridge, there is no requirement to maintain crew on permanent watch in the safety centre in addition to the bridge. However, suitable alarms are to be provided at the conning position in the bridge, so that the crew on watch there may be aware of any event needing attention at the safety centre.

When the safety centre is not part of the bridge, it may or may not be permanently manned. If it is not manned permanently, relevant alarms are required at the bridge, so as to warn the crew on watch there of any developing emergency.

[MSC.1/Circ.1368]

11.3.2.3 Functions

Operation, control and monitoring of the following key safety systems are required from the safety centre:

- all powered ventilation systems;
- fire doors;
- general emergency alarm system;
- public address system;
- electrically powered evacuation guidance systems;
- watertight and semi-watertight doors;
- indicators for shell doors, loading doors and other closing appliances;
- water leakage of inner/outer bow doors, stern doors and any other shell door;
- television surveillance system;
- fire detection and alarm system;
- fixed fire-fighting local application system(s);
- sprinkler and equivalent systems;
- water-based fire-extinguishing systems for machinery spaces;
- alarm to summon the crew;
- atrium smoke extraction system;
- flooding detection systems; and
- fire pumps and emergency fire pumps.

[SOLAS II-2/23.6]

The exact functionalities required for each system as well as redundancies between the bridge and the safety centre are listed in MSC.1/Circ.1368 Appendices 1 and 2 [39]. The list of required functionalities is copied below in Table 14 for ease of reference.

Table 14 - Functionality of systems to be located in onboard safety centre functional requirements

System	Operation and control	Monitoring	Alarm
Powered ventilation systems *For ro-ro ships, SOLAS regulation II-2/20.3.1.3 applies.*	X	X	X
Fire doors	X	X	
General emergency alarm system	X		
Public address system	X		
Electrically-powered evacuation guidance systems	X		
Watertight and semi-watertight doors	X	X	X
Indicators for shell doors, loading doors and other closing appliances		X	X
Water leakage of inner/outer bow doors, stern doors and any other shell door		X	X
Television surveillance system		X	
Fire detection and alarm system	X	X	X
Fixed fire-fighting local application system(s)		X	X
Sprinkler and equivalent systems		X	X
Water-based systems for machinery spaces		X	X
Alarm to summon the crew	X		
Atrium smoke extraction system	X		
Flooding detection systems			X
Fire pumps and emergency fire pumps	X	X	

[MSC.1/Circ.1368 Appendix 1]

11.3.3 Arrangement and ergonomics

11.3.3.1 General

It is to be noted that SOLAS V/15 [5] contains provisions for bridge design and ergonomics, especially aiming at ensuring “promoting effective and safe bridge resource management”.

[SOLAS V/15]

Although rather oriented towards safety of navigation, the associated IMO Guidelines, MSC.1/Circ.982 [42], also apply to the design of the safety workstation in the bridge, and include a few interesting recommendations covering:

- General habitability recommendations (lighting, ventilation, occupational safety etc.);
- Workstation arrangement and location;
- Control locations and design;
- Display arrangements; and
- Alarm design and management.

MSC.1/Circ.982 [42] is taken as reference for the design of both the bridge and the safety centre.

[NAV 55/12] [43]

It is to be noted that the use of an integrated computer technology in the safety centre is authorized, provided the hierarchy of computer and control systems is clearly documented and a failure in the computer system will not compromise the operation of the ship safety systems.

[MSC.1/Circ.1368 §6 and 7]

For other safety systems than fire alarm and detection system (see below §11.3.3.3), the operation with the integrated system shall be at least as effective as it would be with individual, standalone systems. Failure of one part of the integrated system is not to affect the functionality of the other parts. Specific measures and justifications are required in order to achieve this requirement.

[BV NR467 Pt C, Ch 2, Sec 3 [3.4.1] & [3.4.2] & Ch 3, Sec 3, Table 2 & [8.1] & Pt F, Ch 3, Sec 4, [4.1.3]] [44] and [18]

11.3.3.2 Communication tools

SOLAS [5] requires suitable communication tools between either the safety centre or the central control station and the wheelhouse and other key control stations on board the ship, as well as a public address system allowing to reach any part in the ship.

[SOLAS II-2/3.9, SOLAS II-2/12, SOLAS II-2/23.5]

11.3.3.3 Fixed fire alarm and fire detection system

For the fixed fire alarm and fire detection system, IMO FSS Code [21] specifies:

- Which systems may exchange information with the fixed fire alarm and fire detection system; and

[FSS Code Ch 9 §2.1.2]

- Under which circumstances the controls of the fixed fire alarm and fire detection system may be coupled with a decision management system.

[FSS Code Ch 9 §2.1.3]

In addition, it may be noted that IMO FSS Code [21] requires that a control panel, approved according to dedicated standards, is provided with the fixed fire detection and fire alarm system. For practical purposes, a dedicated control panel is usually provided with the fixed fire alarm and fire detection system – which may then be interconnected with a limited number of other functionalities within the limitations given by FSS Code Ch 9 §2.1.2 and §2.1.3 as mentioned above.

[IMO FSS Code Ch 9 §2.3.2]

Further detail on the control and monitoring requirements for the fixed fire alarm and fire detection system can be found in Chapter 16.2.

11.4 Operational aspects

The problem on board the vessels in a critical situation such as fire, is that it is difficult to get and maintain an overview of the situation. Both to begin with and as it evolves. Even though fire-drills are held frequently, there is a discrepancy between practice and real case scenarios that is hard to gap. No matter how good and dedicated the crew are to safety and fire-drills they will not be able to get the same experience level as on shore firefighters and fire marshals, as their primary jobs are that of seamen. It would be of value to develop tools to help the crew getting an overview of the fire situation and maintaining it.

In broad terms Figure 9 describes the seven steps that occur if a fire breaks out on board a vessel. The crew is to be familiarised with the vessel beforehand and must know their muster stations. Fire drills are held according to SOLAS regulations every week on ro-pax vessels and every month for ro-ro and cargo vessels. On DFDS vessels drills are held every second week when the entire crew changes[11]. This ensures that the crew knows their roles, responsibilities, and mustering stations. Furthermore, there will always be a familiarisation process for new crew members on-board a vessel, to ensure that they are familiar with the procedures on board.

Examples of a mustering plan for a ro-ro vessel is shown at Figure 10 and for a ro-pax vessel can be found in the ANNEX .

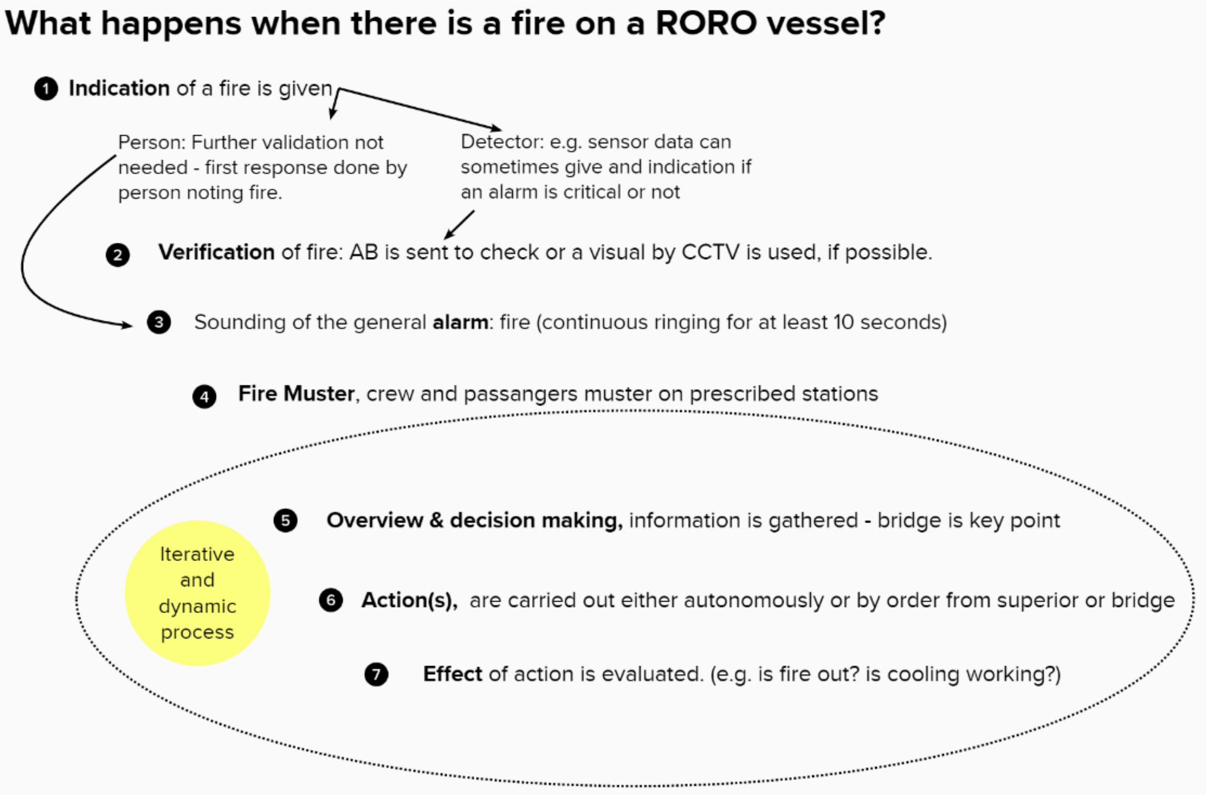


Figure 9. The seven steps of firefighting on board

The actions and information flow on a ro-ro vessel are described in Figure 10. presenting an example to generalize the process, which is not vessel specific. However, as vessels differ it is not an easy process to generalize. In reality there will be changes both to how these flows are on different vessels (design, crew, other vessel specific procedures etc.) and to how the situations evolve (missing persons, other critical situations evolving parallel to the fire, human reactions to crises, failing of essential equipment, bad weather etc.).

The seven steps are, in general, applicable for all ro-pax vessels, with the exception that passengers are involved differently depending on a particular vessel. On DFDS's passenger vessels the fire alarm will initially only sound in the crew area unless the fire is also affecting the passenger safety. For example, if the fire starts in the engine room, there is no need to call out to the entire vessel and make the passengers afraid and stressed. In this case, when the fire is put out and everything is under control the Captain will make an announcement to the passengers. If the fire is spreading or causing a risk to the passengers, the alarm will be sounded all over the vessel and precautions will be taken. Handling a fire on a passenger vessel is quite different from a cargo vessel regarding how to manage the crew

[11] The drills of the crew must take place within 24 hours of the vessel leaving a port if more than 25 percent of the crew have not participated in abandon-ship and fire drills on board that particular vessel in the previous month.

on board. On a passenger vessel, there are more crew, and to rotate firefighting teams over an extended period of time is not as demanding as on a ro-ro vessel.

11.4.1 Objectives

When any critical situation arises on board, the main objective is to protect human life, and only then assets. This means that safety concerns for the crew comes before cargo or vessel damage. However, if at minimum risk the vessel and cargo can be saved, this should be sought, both for obvious economic reasons but also for the fact that is safer for crew and passengers to stay on board the vessel as long as possible. During a fire on board a vessel this is the main objective of decision makers.

11.4.2 Equipment available at the Fire Resource Management Centre

11.4.2.1 Communication on board

Communication on board is done with VHF or UHF radios. A common communication channel is agreed upon as standard, used both for drills and in emergency situations. Some vessels operate using two channels, one between the fire commander and the firefighting teams and one for the rest of the crew. Other vessels have a ”priority channel” where communication on the line can be interrupted by the commands from the captain (just like channel 16 is set in most radios for traffic information).

11.4.2.2 Communication outside of the vessel

For communication between ship and externals, VHF radio (channel 16) can be used both to talk and to send out mayday text messages. The satellite phone connection (or regular phone connections if close to shore) can also be used as well as the ship’s e-mail and internet connection, but the latter will typically not be primary line of communication if there is a fire on board.

11.4.2.3 Fire Panels

Fire panels show the detectors and the alarm notifications – please see Chapter 9 and Figure 21 for illustration.

11.4.2.4 Cargo

The cargo stowage plan is also considered. On DFDS vessels the brand *LoadStar* is used for stowage planning (trim and stability calculations). Positions of all IMDG trailers are known and recorded and in case of fire this information is considered before course of action is decided. All IMDG must be checked by the duty officer before it can be allowed to be loaded on board the vessel. This implies that the duty officer most likely will be asked to confirm any doubts or concerns regarding the IMDG (often the duty officer is the Chief officer). On DFDS vessels it is not recorded if a vehicle is fossil fuel driven or electric. Reefer unit locations are known.

11.4.2.5 CCTV

There is also access to CCTV cameras on most vessels, however CCTV coverage does not need to be complete or view can be blocked due to smoke, cargo etc.

11.4.2.6 Automation

Vessels have various degrees of the possibility to automatically control fire-dampers, fire-pumps, bilge-pumps, drenchers and inert gas extinguishers from the fire resource management centre. This is typically depending on age and vessel design.

11.4.2.7 Navigational aids

The ship still needs to be navigated safely in case of fire, therefore the usual navigational means like AIS, electronic charts (ECDIS) and radars are used.

11.4.2.8 Stand-by crew

The crew members who are not directly signed on to a certain duty on the muster-list shall be stand-by on the bridge. They can be asked to relay communications if radio-signals are weak, help where more hands are needed to already be defined tasks or newly risen tasks. If they are set on a job they will be noted on the fire-logbook, as well as they will be told to report to the person in need of their assistance to keep track of all persons on board.

11.4.2.9 Log of events

When fire breaks out onboard a ship, a fire log will be started. The regular logbook where ship positions, speed, course etc. are logged is not used for this task. Typically, the 1st mate (on ro-ro vessels) will start writing the fire logbook documenting all actions and developments with time and a short description. This is done to keep an overview of events and to be able to document what happened on board afterwards. It can be vital to know, for the bridge and fire-commander when planning, if a fire-fighting team have been in action for more than 20 minutes, as it must be expected that they then soon need both refilling of air and a break to be ready for the next run.

On Pearl Seaways (and other ro-pax vessels with similar setup) only the Captain is present on the bridge. The chief officer and the first mate muster with either the limitation group or at the hospital depending on which safety card they have. The limitation group are the ones in charge of boundary cooling and stopping of the fire spread. To improve training and motivation it is possible to switch roles for crew next to each other in rank. To be noted; this is how the crew is organized on Pearl Seaways, other vessels might do it differently.

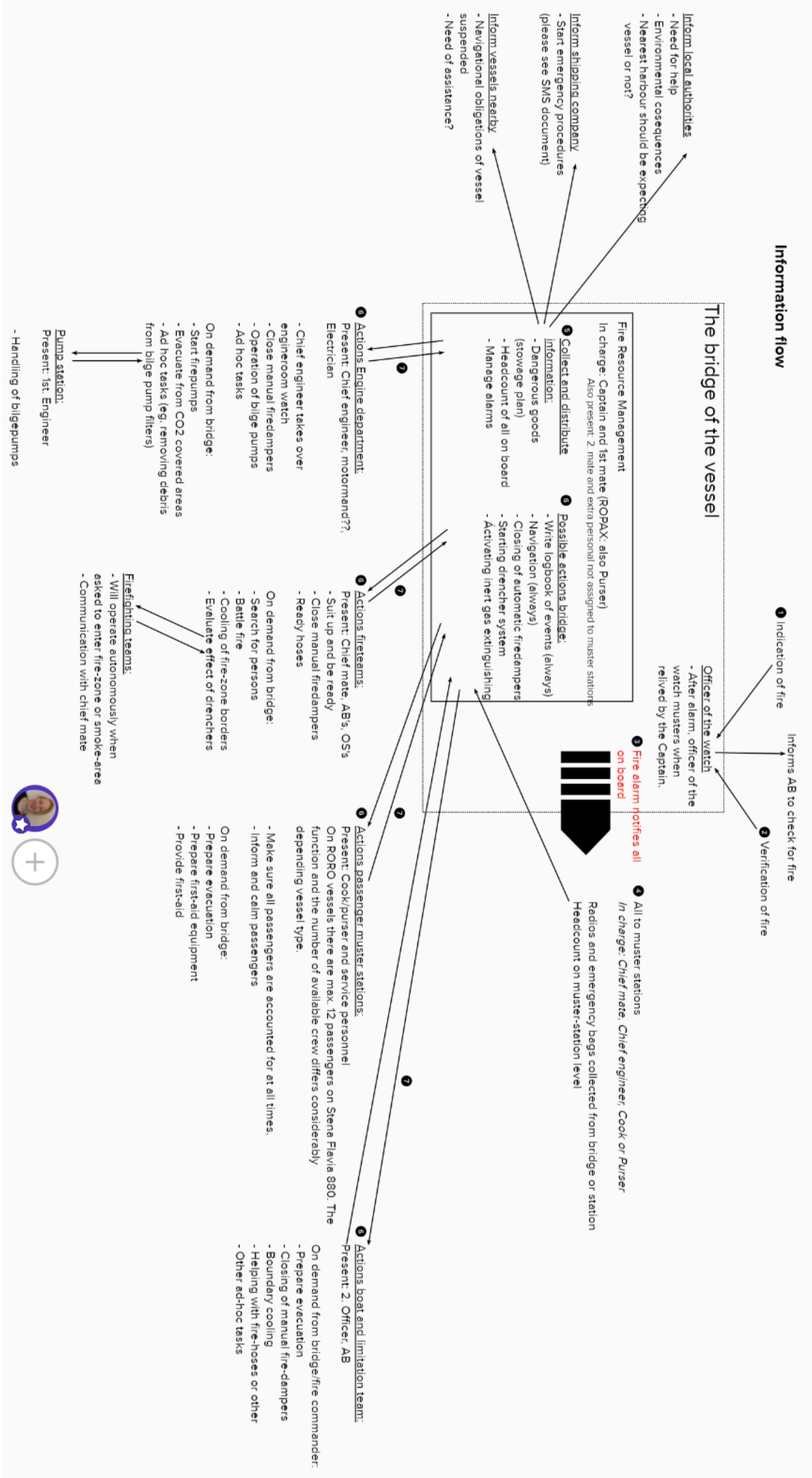


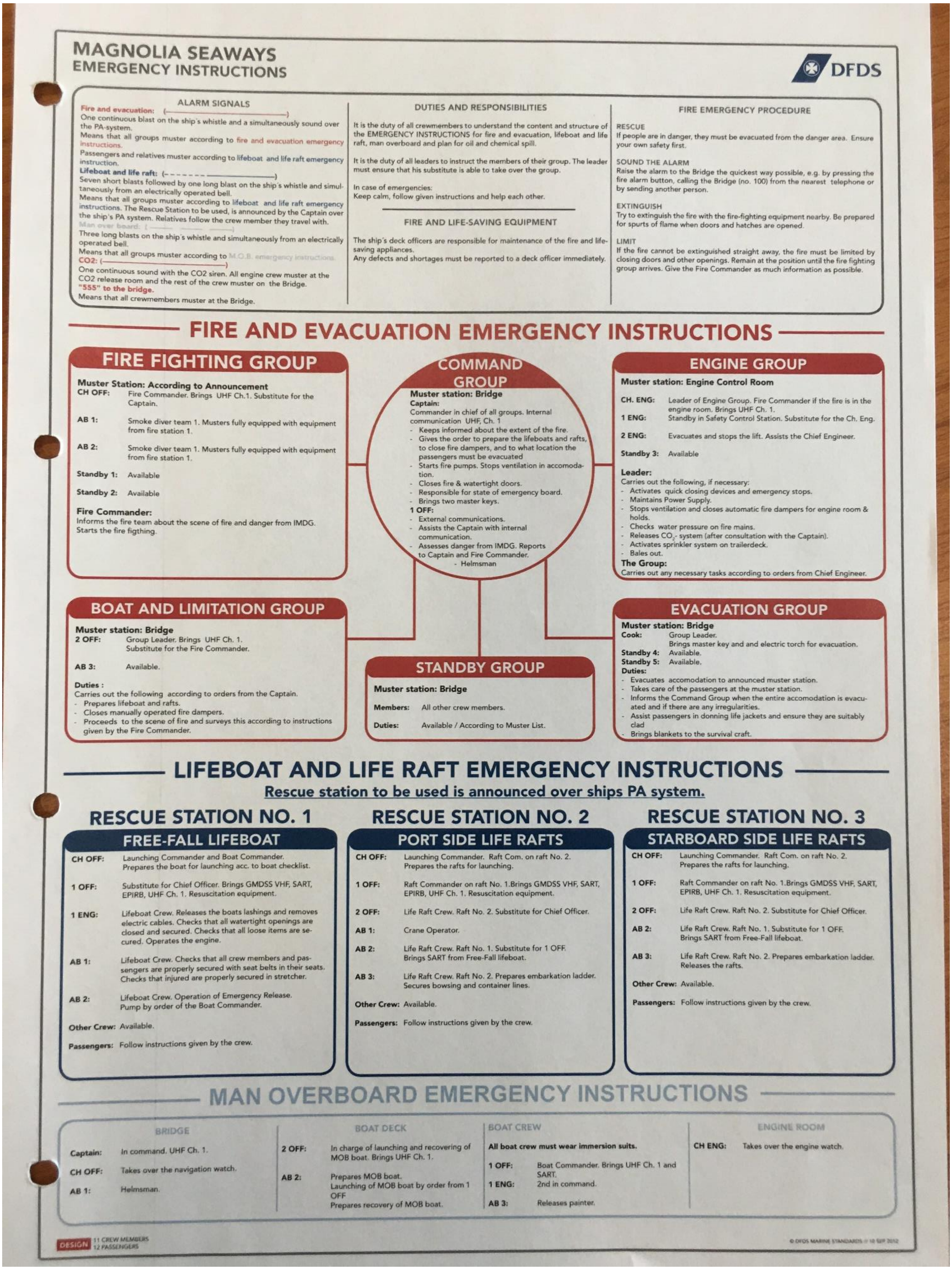
Figure 10. Actions and information flow on a ro-ro vessel

11.4.2.10 Examples from Magnolia Seaways

On a ro-ro vessel there is less focus on handling passengers than on the ro-pax vessels as there are maximum 12 passengers on board, their cabins are normally located close to the crew mess and crew cabins. The cook and service personnel have the responsibility for the 12 passengers and for providing first-aid if needed.

The mustering plan of Magnolia, illustrated on Figure 11, shows how this system is divided. On the mustering plan it is also noted who is to replace whom in case someone is hurt or missing. Please note that normally the chief officer is responsible for the coordination and direct battling of the fire. However, if the fire is in the engine department the role of fire commander will go to the chief engineer to make sure that the person with the most knowledge of the area is in charge.

Talking to the safety officer on Magnolia Seaways it was underlined that on the freight vessels, management of crew as a resource is essential to take into consideration right from the beginning. A fire on board can take a hard toll on the crew and last for many hours before resolved. To have available firefighters during this time can be quite a logistic challenge.



MAGNOLIA SEAWAYS
EMERGENCY INSTRUCTIONS

DFDS

ALARM SIGNALS

Fire and evacuation: (——————————————)
One continuous blast on the ship's whistle and a simultaneously sound over the PA-system.
Means that all groups muster according to fire and evacuation emergency instructions.
Passengers and relatives muster according to lifeboat and life raft emergency instruction.
Lifeboat and life raft: (– – – – – – – ———————)
Seven short blasts followed by one long blast on the ship's whistle and simultaneously from an electrically operated bell.
Means that all groups muster according to lifeboat and life raft emergency instructions. The Rescue Station to be used, is announced by the Captain over the ship's PA system. Relatives follow the crew member they travel with.
Man over board: (——— ——— ———)
Three long blasts on the ship's whistle and simultaneously from an electrically operated bell.
Means that all groups muster according to M.O.B. emergency instructions.
CO2: (——————————————)
One continuous sound with the CO2 siren. All engine crew muster at the CO2 release room and the rest of the crew muster on the Bridge.
"555" to the bridge.
Means that all crewmembers muster at the Bridge.

DUTIES AND RESPONSIBILITIES

It is the duty of all crewmembers to understand the content and structure of the EMERGENCY INSTRUCTIONS for fire and evacuation, lifeboat and life raft, man overboard and plan for oil and chemical spill.

It is the duty of all leaders to instruct the members of their group. The leader must ensure that his substitute is able to take over the group.

In case of emergencies:
Keep calm, follow given instructions and help each other.

FIRE AND LIFE-SAVING EQUIPMENT

The ship's deck officers are responsible for maintenance of the fire and life-saving appliances.
Any defects and shortages must be reported to a deck officer immediately.

FIRE EMERGENCY PROCEDURE

RESCUE
If people are in danger, they must be evacuated from the danger area. Ensure your own safety first.

SOUND THE ALARM
Raise the alarm to the Bridge the quickest way possible, e.g. by pressing the fire alarm button, calling the Bridge (no. 100) from the nearest telephone or by sending another person.

EXTINGUISH
Try to extinguish the fire with the fire-fighting equipment nearby. Be prepared for spurts of flame when doors and hatches are opened.

LIMIT
If the fire cannot be extinguished straight away, the fire must be limited by closing doors and other openings. Remain at the position until the fire fighting group arrives. Give the Fire Commander as much information as possible.

FIRE AND EVACUATION EMERGENCY INSTRUCTIONS

FIRE FIGHTING GROUP

Muster Station: According to Announcement

CH OFF:	Fire Commander. Brings UHF Ch.1. Substitute for the Captain.
AB 1:	Smoke diver team 1. Musters fully equipped with equipment from fire station 1.
AB 2:	Smoke diver team 1. Musters fully equipped with equipment from fire station 1.
Standby 1:	Available
Standby 2:	Available

Fire Commander:
Informs the fire team about the scene of fire and danger from IMDG.
Starts the fire figthing.

COMMAND GROUP

Muster station: Bridge
Captain:
Commander in chief of all groups. Internal communication UHF, Ch. 1
- Keeps informed about the extent of the fire.
- Gives the order to prepare the lifeboats and rafts, to close fire dampers, and to what location the passengers must be evacuated
- Starts fire pumps. Stops ventilation in accomodation.
- Closes fire & watertight doors.
- Responsible for state of emergency board.
- Brings two master keys.

1 OFF:
- External communications.
- Assists the Captain with internal communication.
- Assesses danger from IMDG. Reports to Captain and Fire Commander.
- Helmsman

ENGINE GROUP

Muster station: Engine Control Room

CH. ENG:	Leader of Engine Group. Fire Commander if the fire is in the engine room. Brings UHF Ch. 1.
1 ENG:	Standby in Safety Control Station. Substitute for the Ch. Eng.
2 ENG:	Evacuates and stops the lift. Assists the Chief Engineer.
Standby 3:	Available

Leader:
Carries out the following, if necessary:
- Activates quick closing devices and emergency stops.
- Maintains Power Supply.
- Stops ventilation and closes automatic fire dampers for engine room & holds.
- Checks water pressure on fire mains.
- Releases CO_2- system (after consultation with the Captain).
- Activates sprinkler system on trailerdeck.
- Bales out.

The Group:
Carries out any necessary tasks according to orders from Chief Engineer.

BOAT AND LIMITATION GROUP

Muster station: Bridge

2 OFF:	Group Leader. Brings UHF Ch. 1. Substitute for the Fire Commander.
AB 3:	Available.

Duties :
Carries out the following according to orders from the Captain.
- Prepares lifeboat and rafts.
- Closes manually operated fire dampers.
- Proceeds to the scene of fire and surveys this according to instructions given by the Fire Commander.

STANDBY GROUP

Muster station: Bridge

Members:	All other crew members.
Duties:	Available / According to Muster List.

EVACUATION GROUP

Muster station: Bridge

Cook:	Group Leader. Brings master key and and electric torch for evacuation.
Standby 4:	Available.
Standby 5:	Available.

Duties:
- Evacuates accomodation to announced muster station.
- Takes care of the passengers at the muster station.
- Informs the Command Group when the entire accomodation is evacuated and if there are any irregularities.
- Assist passengers in donning life jackets and ensure they are suitably clad
- Brings blankets to the survival craft.

LIFEBOAT AND LIFE RAFT EMERGENCY INSTRUCTIONS

Rescue station to be used is announced over ships PA system.

RESCUE STATION NO. 1

FREE-FALL LIFEBOAT

CH OFF:	Launching Commander and Boat Commander. Prepares the boat for launching acc. to boat checklist.
1 OFF:	Substitute for Chief Officer. Brings GMDSS VHF, SART, EPIRB, UHF Ch. 1. Resuscitation equipment.
1 ENG:	Lifeboat Crew. Releases the boats lashings and removes electric cables. Checks that all watertight openings are closed and secured. Checks that all loose items are secured. Operates the engine.
AB 1:	Lifeboat Crew. Checks that all crew members and passengers are properly secured with seat belts in their seats. Checks that injured are properly secured in stretcher.
AB 2:	Lifeboat Crew. Operation of Emergency Release. Pump by order of the Boat Commander.
Other Crew:	Available.
Passengers:	Follow instructions given by the crew.

RESCUE STATION NO. 2

PORT SIDE LIFE RAFTS

CH OFF:	Launching Commander. Raft Com. on raft No. 2. Prepares the rafts for launching.
1 OFF:	Raft Commander on raft No. 1.Brings GMDSS VHF, SART, EPIRB, UHF Ch. 1. Resuscitation equipment.
2 OFF:	Life Raft Crew. Raft No. 2. Substitute for Chief Officer.
AB 1:	Crane Operator.
AB 2:	Life Raft Crew. Raft No. 1. Substitute for 1 OFF. Brings SART from Free-Fall lifeboat.
AB 3:	Life Raft Crew. Raft No. 2. Prepares embarkation ladder. Secures bowsing and container lines.
Other Crew:	Available.
Passengers:	Follow instructions given by the crew.

RESCUE STATION NO. 3

STARBOARD SIDE LIFE RAFTS

CH OFF:	Launching Commander. Raft Com. on raft No. 2. Prepares the rafts for launching.
1 OFF:	Raft Commander on raft No. 1.Brings GMDSS VHF, SART, EPIRB, UHF Ch. 1. Resuscitation equipment.
2 OFF:	Life Raft Crew. Raft No. 2. Substitute for Chief Officer.
AB 2:	Life Raft Crew. Raft No. 1. Substitute for 1 OFF. Brings SART from Free-Fall lifeboat.
AB 3:	Life Raft Crew. Raft No. 2. Prepares embarkation ladder. Releases the rafts.
Other Crew:	Available.
Passengers:	Follow instructions given by the crew.

MAN OVERBOARD EMERGENCY INSTRUCTIONS

BRIDGE

Captain:	In command. UHF Ch. 1.
CH OFF:	Takes over the navigation watch.
AB 1:	Helmsman.

BOAT DECK

2 OFF:	In charge of launching and recovering of MOB boat. Brings UHF Ch. 1.
AB 2:	Prepares MOB boat. Launching of MOB boat by order from 1 OFF. Prepares recovery of MOB boat.

BOAT CREW

All boat crew must wear immersion suits.

1 OFF:	Boat Commander. Brings UHF Ch. 1 and SART.
1 ENG:	2nd in command.
AB 3:	Releases painter.

ENGINE ROOM

CH ENG:	Takes over the engine watch.

DESIGN 11 CREW MEMBERS 12 PASSENGERS

Figure 11. Muster Plan Magnolia Seaways

11.4.2.11 Examples from Pearl seaways

On ro-pax vessels the information flow is slightly different than what is shown in Figure 11, and handling of the situation is a more complex due to the handling of so many persons experiencing a critical situation. Normally, the personal in charge of the service department then have the important role of mustering, calming, and manoeuvring the many passengers according to orders from the bridge. On Pearl Seaways they have the procedure to search all cabins leaving a sign on the door that someone from the crew has searched the location. If there is smoke in an area with passenger cabins, the task falls to the firefighting teams. Else personnel from the evacuation group will do the task. This procedure might take some time, and it will therefore take some time before fire resource management can get the information and a full overview.

To help the crew perform better, emergency bags are prepared on the bridge of Pearl Seaways for each muster-stations, providing the crew with the checklists and equipment needed to do what is needed on their respective stations, sparing doubts and need for communication in the first essential minutes.

The following pictures aims to visualise what tools are available on board on the fire resource management centre. The pictures are from Pearl Seaways, taken by Lena Brandt. On Figure 13Figure 13. Fire detection panel – close-up, Pearl Seaways, it is possible to see how the detector-unit's location (1) and (3) is indicated and that the detector knows the difference between smoke and moist in the air (2).

Figure 12. Fire detector panel, Pearl Seaways

Figure 13. Fire detection panel – close-up, Pearl Seaways

At Figure 14Figure 29 it can be seen that the HR-manager (or purser) on board Pearl is keeping track of where every person on board is located. After the muster, the headcount is compared to crew and passenger lists. And they need to add up. When all are accounted for, he will continue to track all personnel, such as fire-fighting teams to keep track of everybody on board the vessel. This is a demanding job, that requires good communication with the different unit leaders such as the engine room team and fire commander. It is a difficult task to share, as miscommunication might cause fatal mistakes, so it is dependent on only one person. On ro-ro vessels this task is combined with the fire logbook and normally taken care of by the 1st mate, as the numbers of people to keep track on is less.

On Figure 15, a fire drill is going on at Pearl Seaways, the standby personnel can be seen lined up at the aft part of the bridge to give space for the captain and others handling the situation. On ro-pax vessels there are more crew to rely on handling ad-hoc tasks during a critical situation, this is not the case on ro-ro vessels.

Figure 14. A leader keeping track of all personnel-units on the vessel and writing logbook of events

Figure 15. Fire drill, Pearl Seaways

Figure 16. CCTV panel on bridge, Pearl Seaways

11.5 Design and production aspects

On some vessels drencher systems can be activated directly from the bridge, otherwise it shall be manned by an engineer on standby to activate drencher-zones from the drencher station by order from the bridge. The first is obviously the better as it frees up a crew member with specialist key knowledge to handle other things as well as actual activation gets faster and less complex.

11.6 Environmental aspects

Water from a fire can be toxic or contain pollution. The same goes for water mixed with foam. As for inert-gasses, it can be fatal if people are entering areas where their concentration is dominant. Smoke and smoke particles are harmful to people as well. However, if the ship must be abandoned it will also have great consequences both environmentally to marine life and safety-wise to people on board the vessel. The people in charge of vessel and crew therefore needs to be concerned with safety of human life and here after the vessel from the fire – how to best avoid polluting environment and threaten marine life. This should preferably be foreseen during design of machinery and viable actions, as how to e.g., avoid pumping dirty water overboard when there is fire on board as such actions cannot be expected to be main concern of decision makers in such a situation.

11.7 Proposal for development and restrictions

For improving the fire resource management centre, a carefully designed layout of centre, bridge and firemen stations is key. This is already a case on some vessels, as example from DFDS fleet, Britan nia and Suecia Seaways both have a good fire resource management centre. Retrofitting is in most cases not a realistic option. Owner's feedback and crew's guidelines are always valuable to help designers understand what is needed in emergency situations on the vessels, during newbuilding design. Better integration and user-interface of the equipment on board could be also a subject for possible improvement.

Information panels or CCTV overview at fire stations might improve intuitive flow of communication towards firefighting teams.

Drones detecting heat scanning the entire vessel can also potentially improve overview of actual situation for crew in charge. However, truly beneficial, the drone should operate autonomously to be truly beneficial, but with the possibility of manual interference if any particular area needs more extensive coverage. The visualisation of drone recordings should be intuitive to read and interpret. Drones with thermal cameras might increase visibility in a fire situation with a lot of smoke.

Small autonomous or remotely controlled units that can operate in cargo spaces and be sent close to scene of action could also be a help in getting the much-needed information of the situation to the fire central. Geometry of space is a big challenge as well as various obstacles and pathfinding. But getting visual of the situation inside the cargo space close to the fire or near the firefighters or reaching the scene of action from angle other than firefighting team would be useful as well.

The skills needed to manage the resources on a vessel during a crisis situation are adapted to crew, vessel and situation. A successful handling of the situation demands good leadership and overview of the captain and officers leading on. Mentioned measures could generally improve situation overview and information flow, which will support prompt decision making.

For the interested reader, please also find more information on this topic in the Master Thesis *The Digital Fire Central* by Thomas Kaland, NTNU, Ref [45].

12 Automatic screening and management of cargo hazards- Action 8-A

Main author of the chapter: Martin Carlsson, STL

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 8-A i.e. Automatic screening and management of cargo hazards.

12.1 Short Description of the addressed Action

The objective of the Action 8-A is to develop and demonstrate a technical solution for automatic screening of cargo to identify fire hazards and develop, utilize and experimentally validate a digital logistics management tool featuring risk-based load planning, through the following tasks:

- Definition of conditions for cargo fire hazard management and database construction
- Assessment of cargo identification technologies
- Assessment of sensors for fire ignition prevention identification
- Fire hazard matching and mapping (Integration software development)
- Stowage planning optimization tool and visualization aid
- Demonstration of vehicle identification tool
- Demonstration of detection of potential ignition sources
- Demonstration of optimization tool and visualization aid
- Appropriate placement of monitoring systems based on hazard map and screening methodologies
- Integration with firefighting control centre

12.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 8-A, i.e. Automatic screening and management of cargo hazards.

12.2.1 Applicable regulations

The present review is based on the regulations listed in Table 15.

.

Table 15: List of documents used for the review of regulations for [Objet]

IMO Documents	SOLAS 74 – International Convention for the Safety Of Life At Sea, as amended
	IMDG Code
	ISM Code – International management code for the safe operation of ships and for pollution prevention
	ISPS Code – International Code For The Security Of Ships And Of Port Facilities
	A.714(17), as amended - Code Of Safe Practice For Cargo Stowage And Securing
	MSC.1/Circ.1440 – Illustrations of segregation of cargo transport units on board containerships and ro-ro ships
	MSC.1/Circ.1471 – Recommendations on safety measures for existing vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion as cargo
	MSC.1/Circ.1588 – Revised emergency response procedures for ships carrying dangerous goods (EMS guide)
IACS & Class Rules	IACS Blue Book, 2019
Flag Administration Rules	-

12.2.2 Requirements

12.2.2.1 Cargo screening

No requirement for automatic cargo screening – with respect to fire safety – has been identified in the international regulations, except that vehicles entering vehicle, ro-ro or special category spaces are assumed to be inspected for leakage, see below [12.2.2.2.3].

12.2.2.2 Management of cargo hazards

12.2.2.2.1 General

SOLAS includes general requirements for cargo proper handling and management of cargo hazards:

- SOLAS II-2/16.2 requires fire safety operational booklets, which are to detail all precautions to be taken when handling the cargoes to be carried onboard and the crew's responsibility in this respect.
  Furthermore, the ISM Code requires that any company operating a ship sets up a safety management system with identified persons in charge of the relevant duties and procedure to report incidents, prepare for and respond to emergency situations;
- SOLAS VI/2 requires that the shipper provides adequate shipping information regarding any cargo loaded onboard;
- SOLAS VI/5 requires proper cargo stowage and securing, referring especially to:
  - The Code of Safe Practice for Cargo Stowage and Securing;
  - The IMDG Code for the carriage of dangerous goods.

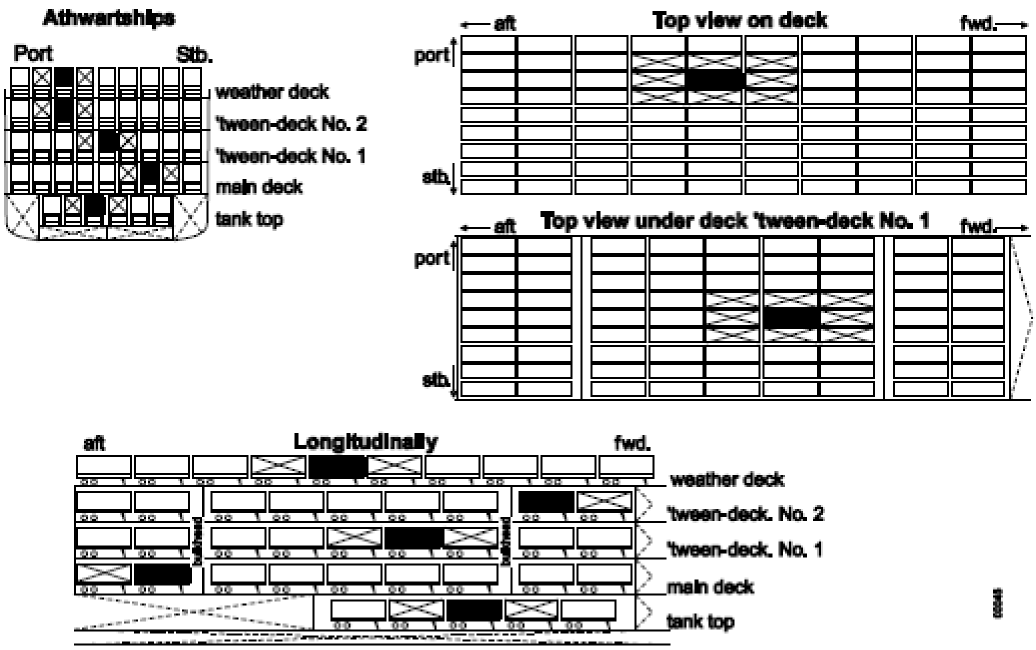
Chapter 7.5 of the IMDG Code focuses on the stowage and segregation of cargo transport units which are transported in ro-ro cargo spaces. In particular, provisions for segregation between cargo transport units onboard ro-ro ships are given in the table included in Reg. 7.5.3.2 (see Table 16).

Table 16: Table of segregation of cargo transport units on board ro-ro ships

Segregation requirement	Horizontal						
		Closed versus closed		Closed versus open		Open versus open	
		On deck	Under deck	On deck	Under deck	On deck	Under deck
"Away from" .1	Fore and aft	No restriction	No restriction	No restriction	No restriction	At least 3 m	At least 3 m
	Athwartships	No restriction	No restriction	No restriction	No restriction	At least 3 m	At least 3 m
"Separated from" .2	Fore and aft	At least 6 m	At least 6 m or *one* bulkhead	At least 6 m	At least 6 m or *one* bulkhead	At least 6 m	At least 12 m or *one* bulkhead
	Athwartships	At least 3 m	At least 3 m or *one* bulkhead	At least 3 m	At least 6 m or *one* bulkhead	At least 6 m	At least 12 m or *one* bulkhead
"Separated by a complete compartment or hold from" .3	Fore and aft	At least 12 m	At least 24 m + deck	At least 24 m	At least 24 m + deck	At least 36 m	*Two* decks or *two* bulkheads
	Athwartships	At least 12 m	At least 24 m + deck	At least 24 m	At least 24 m + deck	Prohibited	Prohibited
"Separated longitudinally by an intervening complete compartment or hold from" .4	Fore and aft	At least 36 m	*Two* bulkheads or at least 36 m + *two* decks	At least 36 m	At least 48 m including *two* bulkheads	At least 48 m	Prohibited
	Athwartships	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited

In this regard, MSC.1/Circ.1440 aims to facilitate the familiarization with these requirements and to support training of relevant personnel by providing illustrations applicable to the segregation requirements on ro-ro ships (example of illustration is provided in Figure 17).

"SEPARATED FROM" .2		
CLOSED VERSUS CLOSED	ON DECK	UNDER DECK
FORE AND AFT	At least 6 metres	At least 6 metres or ONE bulkhead
ATHWARTSHIPS	At least 3 metres	At least 3 metres or ONE bulkhead



2 – Situation *closed* versus *closed*

Note: All bulkheads and decks shall be resistant to fire and liquids.

Figure 17: Illustration of segregation requirements on ro-ro ship (for the situation Closed versus Closed) extracted from MSC.1/Circ.1440

As a side note, it is outlined that the Ship Security Assessment required by IMO ISPS Code for ship security purposes normally includes cargo screening, including dangerous cargo and with a focus on unaccompanied luggage, as outlined by IACS Rec.81.

12.2.2.2.2 Dangerous goods

When dangerous goods are carried on ro-ro decks, IMO IMDG Code applies and details, for each product or class of dangerous good:

- Stowage and packaging rules (inside the container or tank);
- Onboard stowage and segregation rules;
- Provisions in case of an incident and fire precautions.

The above is complemented by "The EmS Guide: Emergency Response Procedures for Ships Carrying Dangerous Goods" which includes detailed recommendations and schedules for each class of dangerous goods in case of fire or spillage.

[IMO IMDG Code is made mandatory by SOLAS VII for the carriage of dangerous goods]

12.2.2.2.3 Vehicles

When they are carried in a vehicle, special category or ro-ro space, vehicles do not fall in the scope of the above-mentioned IMDG Code. However, it can be outlined that IMDG Code however mentions that there should be “no signs of leakage from the battery, engine, fuel cell, compressed gas cylinder or accumulator, or fuel tank when applicable.”

[IMDG Code Ch 3.3 SP 961. This recommendation is provided as a condition for vehicles carried in vehicles, special category or ro-ro spaces for not being subject to IMDG Code]

12.2.2.2.3.1 Vehicles with compressed hydrogen or compressed natural gas

It may be mentioned that SOLAS II/20-1 provides additional safety measures for vehicle carriers with vehicle and ro-ro spaces intended for carriage of motor vehicles with compressed hydrogen or compressed natural gas in their tanks for their own propulsion as cargo.

In particular, MSC.1/Circ.1471 recommends that “the shipper should provide a signed certificate or declaration that the vehicle fuel system, as offered for carriage, has been checked for leak-tightness and the vehicle is in proper condition for carriage prior to loading. In addition, the shipper is to mark, label or placard each vehicle, after it has been checked for leak-tightness and that it is in proper condition for carriage. During loading, the crew should check each vehicle for the shipper’s markings”.

[SOLAS II-2/20-1 and MSC.1/Circ.1471]

12.2.3 Other regulations

12.2.3.1 Screening of container mass

It is to be noted that SOLAS VI/2.3 requires that the gross mass of cargo units to be checked by the shipper.

In addition, for containers (except those that are carried on a trailer on ro-ro ships engaged in short international voyages), SOLAS VI/2.4 to 2.6 make it mandatory that the shipper performs an effective weighing of the packed containers or of all the items contained in the container. This VGM (Verified Gross Mass) regulation has entered into force in July 2016 and has been issued in the wake of the dramatic loss of the MOL Comfort in the Indian Ocean in June 2013.

12.3 Operational aspects

Screening of vehicles at terminal must consider the time span from scanning to loading. Scanning should be done as late as possible from heat scanning point of view as some raised temperature situations may cool down by itself before imposing a hazard onboard. On the other hand, from information validation point of view, this should be done as soon as possible upon arrival at the terminal. Further, scanning may be performed in steps: Information validation scanning on arrival to terminal and heat scanning just before loading on board the ship.

Generally, the same cargo data is processed several times in the transport process. Automatic data processing and integration with freight office and/or other relevant systems, would leave to the crew more time for other important activities.

Stowage lanes impose a fire hazard, and systems for automatic screening can reduce the fire risks, such as:

- Attempts to enter terminal or vessel
- In vehicles on arrival and at time of loading

- In vehicles spaces during voyage

Vehicle management system at Stena, are presented in ANNEX G:

- Hoek van Holland infrastructure in place for tests for automatic screening of incoming vehicles. Stowage lanes situation critical;
- Karlskrona GateLAB;

Safety centers arrangement and system used on board Stena vessels are listed below:

- Stena Jutlandica: Dedicated room adjacent to bridge. Partially integrated systems, Consilium
- Stena Hollandica: Designated area on SB side of bridge. Integrated systems to some extent but not full potential used
- Stena Transporter: No specific location for safety response, master brings Safety Binder to the maneuvering console. No integrated system.
- Ark Futura: A cluster of systems on aft navigation bridge bulkhead. No integrated system, unacceptable user interface.

Regarding the cargo stowage plan on short voyages, in many cases, the final layout is received by the freight office, only about 30 minutes before the arrival (typical for 1 h turnaround operation). Cargo stowage planning is made by the 2nd Officer in cooperation with the Chief Officer. Number of cars is most often only an approximate forecast.

12.4 Design and production aspects

The cargo sreening equipment shall be designed to cover all range of cargo that can be loaded onboard and stowed on all types of cargo spaces. The system shoud be capable to witstand the relevant operational (vibrations, heat, exhaust gases, etc) and enviromental conditions (weather conditions, ice, salt spray, sea water, sunlight, etc). Further, cconsideration must be made on the cargo screening system installation site (on-shore or on-board), to cover the world fleet and world ports requirements. It is assumed that not all ports will have the automatic screening systems installed. A possible intermediate solution to be considered implies a mobile screening equipment not dependent of the port and/or vessels equipment. For example, a vehicle equipped with a screening portal, stowed onboard during sailing that could be used for ports with no sophisticated equipment.

The cargo screening system shall be integrable with ship systems and shall not interfere (or as less as possible) with the cargo holds design parameters (clear height, clear breadth, rampway equipment, Cargo area, typical stowaways, etc).

12.5 Proposal for development and restrictions

Proposals for development and restrictions from a design, production and operational aspects are listed below:

- booking system shall be used as one source and storage place for hazard information;
- booking/cargo data validation, without additional manual checking;
- Automated vehicle positioning system or automated location mapping during loading
- APVs identification;
- Electric car monitoring: battery temperature trends or gas ventilation caused by thermal runaway;

- Battery status monitoring and interaction (Mode 3 & 4 communication) with the Charging station and BMS systems, status signal connections to ship system;
- use of fixed ship mounted charging cables only;
- Condition monitoring by physical connection of the reefer unit CPU or via WiFi/GSM
- Stena IR camera project Alphatron to be considered, see ANNEX G:
  - Equipment tested for weather deck on Stena Transporter, Lloyds “approved”,
  - Further introduction of same function on open and closed decks of Stena Transporter (test planned shortly),
  - FIKE heat detection system tested on Stena Scandinavica;
- Presentation of information to OOW, safety center and ECR by a system that automatically identifies any special requirements to the cargo surrounding the fire as well as providing recommendations for the OOW on the actions to be taken. Cargo hazard information would be useful to access if a fire alarm is sounded;
- Integrated presentation to crew, through a universal fire safety app;
- Big data analysis to provide a simplified and essential information for manual activities
- Status of reefer units to be considered as follows:
  - Connection to booked units via GSM. According to available information, it is possible for “modern” units
  - Hardwire into diagnostics interface;
  - Heat detection on arrival and during voyage (cameras, intelligent stickers, one time or semi-permanent if travelling a lot with operator) low cost, common standard for ro-pax industry
  - status information during voyage available
  - Selection possibility for manual checks on arrival of vessel to terminal and/or special attention during voyage
- Evaluation of best scanning location: In terminal at entry, parking or ramp, on vessel at entry or onboard, by rolling/sliding or flying drone in terminal or vessel
- DFDS is involved in several drone projects for screening the trailers at the terminal or at the weather deck for identification or heat detection. This might prove a way forward.

12.5.1 Fire safety App brainstorming

The following App possibilities are identified:

- Selective information to different stakeholder
- Status information available
- Automatic status report to stakeholders in office and at coast guard, keeping crew free for situation value adding?
- Information/Guidelines on the actions to be taken

Different ambition levels are identified as follows:

- Level 1: Generic, static, information, provided by supplier
- Level 2: Ship specific, static, configuration at time of installation
- Level 3: Situation specific, updated in real time, connected to ship system

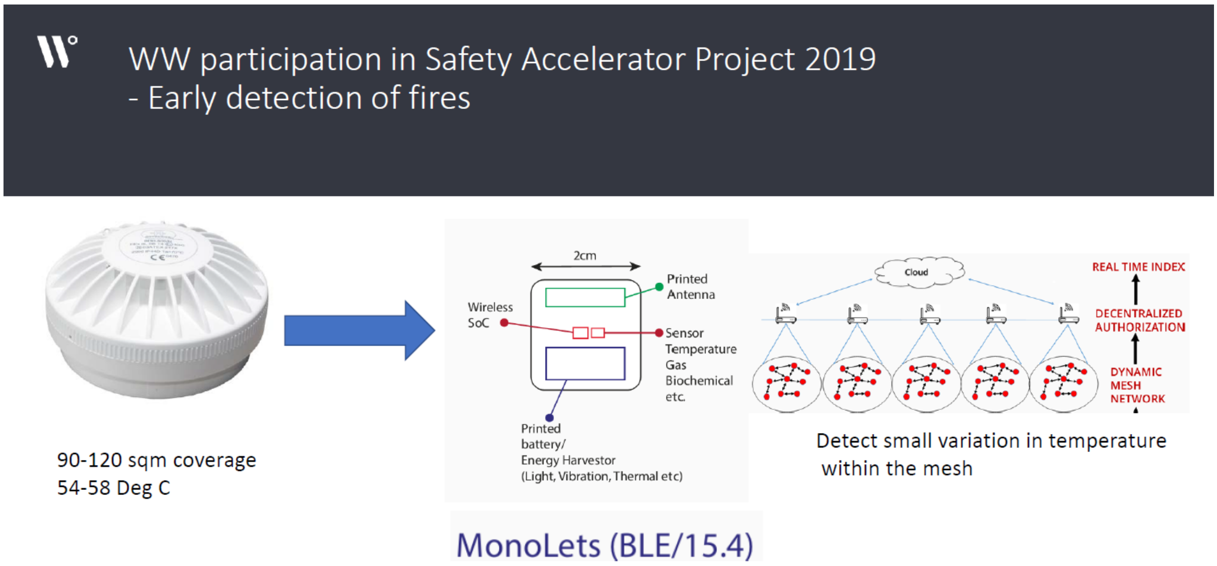


Figure 18. Proposed smart tags for detecting temperature, gas and biochemicals.

For relevant equipment testing, reference shall be made to FIRESAFE I and II projects results, Ref [14].

13 Guidelines and solutions for safe electrical connections - Action 8-B

Main author of the chapter: Martin Carlsson, STL

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 8-B i.e. Guidelines and solutions for safe electrical connections.

13.1 Short Description of the addressed Action

The objective of the Action 8-A is to develop guidelines for safe electrical power connections in ro-ro spaces (refrigerated cargo units, charging of electrical vehicles, etc.), considering the design of electrical ship systems, equipment as well as operational procedures, throught the following:

- Definition of conditions and hazards of electrical connections
- Development of safe design of ship electrical systems and equipment
- Development of operational routines for safe electrical connections
- Implementation of systems, equipment and routines for safe electrical connections

13.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 8-B, i.e. “guidelines and solutions for safe electrical connections”. This is understood as covering electrical sockets and associated equipment provided in ro-ro spaces for the connection of reefer containers or electrical vehicles during the voyage.

13.2.1 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

Table 17: List of documents used for the review of regulations for Action 8-B

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in January 2020
	DNVGL Rules for the Classification of Ships, December 2019
	LR Rules and Regulations for the Classification of Ships, July 2019
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 28/12/17 edition

13.2.2 Requirements

13.2.2.1 General

This section describes the general requirements related to Action 8-B and provides the associated reference(s) in the regulatory texts.

13.2.2.2 Explosion proof electrical equipment

In general, electrical equipment, including sockets and shipboard cables, used in ro-ro or vehicle spaces are required to be suitable for use in an explosive petrol and air mixture. For practical purposes, certified safe equipment for Zone 1 is required:

- In special category spaces located below the bulkhead deck, in the whole space.
- In other ro-ro and vehicle spaces, up to 450mm height.

Certified safe equipment for Zone 2 is required in other ro-ro and vehicle spaces, above 450mm height.

[SOLAS II-2/20.3.2]

If the carriage of dangerous goods is foreseen – which may be the case when reefer containers are carried, then the level of protection of the electrical equipment is determined taking into account the exact type of dangerous goods carried.

[SOLAS II-2/19.3.2 & IEC 60092-506]

13.2.2.3 Plugs and sockets

Plugs and sockets themselves are not covered in detail by international IMO regulations. However, a number of requirements aimed at limiting the risk of a fire starting on the sockets can be found in BV Rules [4] for ro-ro passenger ships as well as in LR Rules [5], usually coming from industrial standards such as the IEC series (see IEC 60092-306 [6] or IEC 60309 [7]), including:

- Requirement for an on/off switch on sockets with a current rating above 16A. The switch must be "off" for plugging or unplugging.

[BV NR467 Pt D, Ch 12, Sec 4 [3.4.3], LR Rules for steel ships Pt 6, Ch 2 §13.6.2]

- The temperature rise on the socket is not to exceed 30°C.

[BV NR467 Pt D, Ch 12, Sec 4 [3.4.4], LR Rules for steel ships Pt 6, Ch 2 §13.6.2]

- It should not be possible to create short-circuit due to incorrect plugging.

[BV NR467 Pt D, Ch 12, Sec 4 [3.4.4], LR Rules for steel ships Pt 6, Ch 2 §13.6.2]

Aforementioned requirements are quite standard in the industry and very similar requirements can be found in the Rules of other Classification Societies.

Similarly, BV Rules [4] also require IP 56 protection level for socket outlets installed in vehicle spaces of ro-ro passenger ships, with a view to ensure that such sockets will be "certified safe" and won't be affected by possible washing of the car-deck with water.

This requirement was implemented in BV Rules [4] further to recommendations from the FIRESAFE I study [8]. It is therefore applicable only to ro-ro passenger ships. The exact same requirements have then been included in MSC.1/Circ.1615 [9], i.e. IMO non-mandatory recommendations applicable to ro-ro passenger ships.

[BV NR467 Pt D, Ch 12, Sec 4 [3.4.5] & [3.4.6], MSC.1/Circ.1615 §1.4]

13.2.2.4 Overcurrent protection

BV Rules [4] for ro-ro passenger ships require individual overcurrent, overload and earth fault protection for each socket provided in vehicle spaces. A similar requirement can be found in MSC.1/Circ.1615 [9], i.e. IMO non-mandatory recommendations applicable to ro-ro passenger ships.

[BV NR467 Pt D, Ch 12, Sec 4 [3.4.2], MSC.1/Circ.1615 §1.5]

13.2.2.5 Electrical cables

Electrical cables used for the connection of individual vehicles have recently been reckoned as major sources of electrical fires onboard ro-ro ships. Hence IMO *Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships*, MSC.1/Circ.1615 [9] includes several requirements aimed at:

- Ensuring that only shipboard cables are used for the connection of electrical vehicles or reefer containers in ro-ro or vehicle spaces and that connections are made by the crew rather than by individual drivers.

[MSC.1/Circ.1615 §1.1.1 and 1.6]

- Ensuring that these shipboard cables are in good condition and properly maintained.

[MSC.1/Circ.1615 §1.1, 1.2, 1.3]

13.2.2.6 Fire patrols

Electrical connections for the supply of electricity to vehicles are identified as potential sources of fire and IMO *Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships*, MSC.1/Circ.1615 [9], specifies that the "*conditions of electrical connections and ship's power supply cables to vehicles*" are to be checked by fire patrols.

[MSC.1/Circ.1615 §1.7.1 and 1.8]

In order to assist the fire patrols, "*it is recommended that portable thermal imaging devices be used for screening during fire rounds and upon suspicion to detect hot areas and overheated electrical equipment.*"

[MSC.1/Circ.1615 §1.7.2]

13.3 Operational aspects

In this chapter the operational aspects are presented. Examples of solutions and procedures from Stena's and DFDS's ships can be found in ANNEX H. Further, Firesafe I report, especially Chapter 3, Sections 3.2.1, 3.2.2, 3.2.5-3.2.8. shall be considered, Ref [14].

13.3.1 Connection of reefer units

Number of reefer units varies a lot between routes/vessels, from only few to more than 100 per departure. Reefer fleet is a mix of modern units with remote condition monitoring system to old fashioned units. Various scenarios are listed below. Also refer to Chapter 5.3.4

<u>Ro-pax vessel 1 situation</u>

Reefer cables are pulled to the connection point on reefer unit by the crew, where the actual connection to the unit is, in general, done by the driver. In some cases, exceptionally, the connection is done by the electrician (Gothenburg- Kiel route);

The disconnection of the cables is done by the crew to avoid damages of the cables as in practice it is shown that the disconnection procedure is not performed adequately by the drivers (the drivers very often forget to disconnect the cables);

Cables are disconnected and stowed on on cable reels or coiled manually before arrival.

Ro-pax vessel 2 situation

Reefer units are connected/disconnected by the crew (Electrician)

Ro-pax vessel 3 situation

Reefer units are connected/disconnected by the AB. Screeningis performed by the First fire patrol after departure.

Ro-pax vessel 4-5 situation

Reefer units run on diesel in the open cargo space and weather decks. Reefer units are connected by the driver on closed decks, disconnected by crew. The crew is “supporting” at time of connection on one of the considered vessels.

Port operation

Refrigeration unit electric connections are checked onboard by the crew. If rejected by the check onboard, the units are returned ashore, which is the case few times per year. In some cases when stowed in the closed cargo space and electric system fails, refrigeration units are powered by diesel and run intermittently 1h by the fire patrol).

Reefer units are generally (90% on the considered ports/ships) equipped with remote monitoring, including temperature, position and failure codes. Data is sent to the forwarder, who eventually contacts Stena if required. (Not working outside 4G network?).

Miscellaneous comments

As observed on a ro-pax vessel (February 2020), a reefer unit was parked in the second lane and connected by cable crossing the first lane, before the loading of first lane. This resulted with the crossing of multiple vehicles over the cable.

Reefer temperature may be checked periodically, once every four hours during voyage, depending on the booking arrangements.

13.3.2 Charging of electric vehicles

Excerpt from Ref [14], the study investigating cost effective measures for reducing the risk from fires on ro-ro passenger ships is listed below.

No	Risk area	Cause	Consequence	Prob	Cons	Mitigation
H1	Battery	Overcharging	Thermal runaway -> toxic gas emission & intense fire	Low	High	18, 20, 22
H2	Battery	Charging damaged battery	Thermal runaway -> toxic gas emission & intense fire	Low	High	17, 19, 22
H3	Battery	Fast charging	Thermal runaway -> toxic gas emission & intense fire	N/A	N/A	N/A
H5	Battery	Overcharging or damaged battery	Thermal runaway -> Gas emission -> Explosion in confined spaces	Low	High	14, 34
H6	Battery	Adding SoC by charging	High SoC -> fire more intense	Inherent due to charging	Medium	N/A
H8	Charging station	Short circuit -> Earth fault	Spark, heat generation	Medium	Medium	21, 22
H9	Charging station	Control function failure	Lost control of charging process -> Thermal runaway	Medium	High	21, 22
H10	Charging cable	Poor cable	Cable fire	Medium	Medium	18, 20, 22, 23, 26
H11	Charging cable	Poorly routed cable	Tripping risk, Obstruction at fire fighting, Risk of damage cables	Medium	Medium	23, 25
H12	Charging cable	Disconnection whilst under power	Spark	Very low	Medium	18, 20, 22
H17	Ship system	Poor feeding power quality, blackout	Consequence failure in charging station	High	Medium	22
H19	Ship system	Ship electric system overload	Fire in ship electric system	Medium	Medium	18, 20, 21
H26	Pax activity	Tampering with equipment	Risk of malfunction	Low	Medium	7, 24
H27	Pax activity	Unauthorized connection		Medium	High	7, 18, 19, 24

Excerpts from Ref [15], the Study of safety aspects of carriage and charging of electrical vehicles (cars and minor units) on RoPax vessels, are listed below.

Additional risk comments

1. The major added risk comes with bringing onboard battery cars, regardless of charging. Charging of part of vehicles only adds marginal risk. Adding few more electric cars to a vessel probably adds more fire risk than plugging few of them you already have onboard into charging stations.
2. Risk of fire in an electric battery car is not proven larger during charging than whilst under way. Risk of fire in electric car is not more likely than for a conventional car, probably smaller. [6] Tesla statistics indicates 5% total fire frequency compared to general vehicle population in Norway.
3. Only one known real onboard battery fire incident, Pearl of Scandinavia 2010. The start of fire was a electric converted car with homemade charging cable. The fire was successfully extinguished by means of manual action and use of fixed systems.
4. Risk for charging cable fault is likely smaller than in case of reefer cable due to better cable quality and cable integrity check by charging station.
5. Connection of car battery to a charging system may contribute to increased safety by providing monitoring of condition of battery.
6. If someone today from a white paper would propose to put vehicles with flammable liquids with low flashpoint on car decks we would be equally cautious as facing new challenges of electric cars.
7. Most car fires whilst charging is caused by malfunction in the charging equipment or car electric system, then spreading to car/battery, rather than being caused by battery malfunction.

Charging onboard

18. Make sure 220V sockets on car decks are not used by passengers for unauthorized charging.
19. Never connect vintage or rebuilt vehicles to ship system. *
20. Limit charging power to low risk levels.
21. Install external circuit/earth fault breakers type B per individual or group of charging stations, with shut off in safe location. Also, remote shut off on bridge or ECR. *
22. Ensure that charging stations meets adequate specification:
    a. Level 2 AC charging
    b. Fixed Type 1 & 2 cables with sockets
    c. Mode 3 Safety communication
    d. Internal transformer
    e. IEC 60092-506 for locations where dangerous goods may be transported
    f. IEC 62196-2/3 & IEC 61851-1 for location where no dangerous goods is transported
    g. SOLAS II-2/20-3-2-2 (IP55, T3, 450 mm from deck, 10 cycle air exchange) *
    h. Alternatively, EX requirements acc SOLAS II-2/20-3-2-2*
    i. IP56, protection from mechanical damages, power shut down at malfunction*
    j. Self-check of internal safety functions, automatic shut down
23. If practically possible crew should make connection. If not option for practical or number reasons driver to connect charging cables, crew supports and checks all connections after departure.
24. Clear signage in charging area. *
25. Only ship cables to be used, length of cables to be limited.
26. Maintenance routine for cables to be established, no defect cables to be used. *
27. Separate as far as possible charging area from fire hazards in ship systems such as engine room or battery room.
28. Co-locate charging spots, to enable manual screening and to limited area for any added fixed safety systems. *
29. Detailed vessel specific risk assessment should be made and documented prior to establishing charging facility. *
30. Select charging location with minimum risk of gas spread to accommodation, well away from staircases and ventilation intakes.

13.4 Design and production aspects

In this chapter the design and production aspects are presented.

In addition, development possibilities with the reefer unit itself shall be considered. For more information see Annex H8 - Reefer unit manufacturer statement.

13.4.1 Earth fault detection

Most often, on ships carrying refrigerated cargo, the electrical network is designed as unearthed power supply (IT - insulated terra), where there is no active conductor directly connected to the protective conductor (PE). This has the advantage that the first insulation fault will not lead to automatic tripping of the circuit breaker that protects the dedicated power supply line. In order to detect an insulation fault before a possible second fault at another location in the network (and thus cause a hazard situation) the insulation resistance between active conductors and earth (ship's hull) is continuously monitored with an insulation monitoring device. If the monitored insulation drops below a pre-set value an alarm is activated.

Usually earth faults of the electrical system are monitored and detected only for the complete electrical distribution as a single unit. In this way exact fault source cannot be located in short period of time nor during ongoing operation. Additionally, the crew will very often ignore the earth fault alarm as it is not critical for the ship's operation in an IT electrical system (vastly used on ship's low voltage networks). In such cases we have an ongoing hazard in the cargo space without the crew really being aware nor reacting on it.

The IMO Guideline Circ. 1615 is asking that the electrical system should detect detrimental loads or earth faults so that the affected socket can be isolated. Today in vast majority of the ships this is achieved by installing a circuit breaker in each socket output and a global earth fault detection system described above. Circuit breaker will protect the supply line from severe electrical faults (exp. short circuit or higher overload) but smaller deviations from normal operations will pass undetected and thou still present a possible fire hazard. Earth faults will be detected and alarmed, but amending the fault is very time consuming for the crew, as earth faults are hard to locate without the insulation faults locating system, plus they are not representing critical situation for the ship so are very often left to be dealt with later, which again represents a possible fire hazard.

On a very small number of ships today, we can find insulation fault locators installed. These are capable of localising insulation faults automatically and precisely within a short time and even small deterioration can be detected at an early stage and reported to the crew. In case of further deterioration of the insulation the supply can be disconnected before critical currents are reached. In this way the fault can be isolated before the hazard situation is reached which is not the case with circuit breakers as they can react only on real fault currents. The disadvantage of this system is that it requires a current measuring device - current transformer, for each socket outlet. An additional electronic device to read the measured currents from the current transformer is needed for approximately every twelve current transformers. This additional equipment should be installed in the distribution box of the sockets outlets as so will contribute to the size of the box which is generally located in the cargo area. Additional equipment and software also represent a noticeable additional cost per each socket outlet.

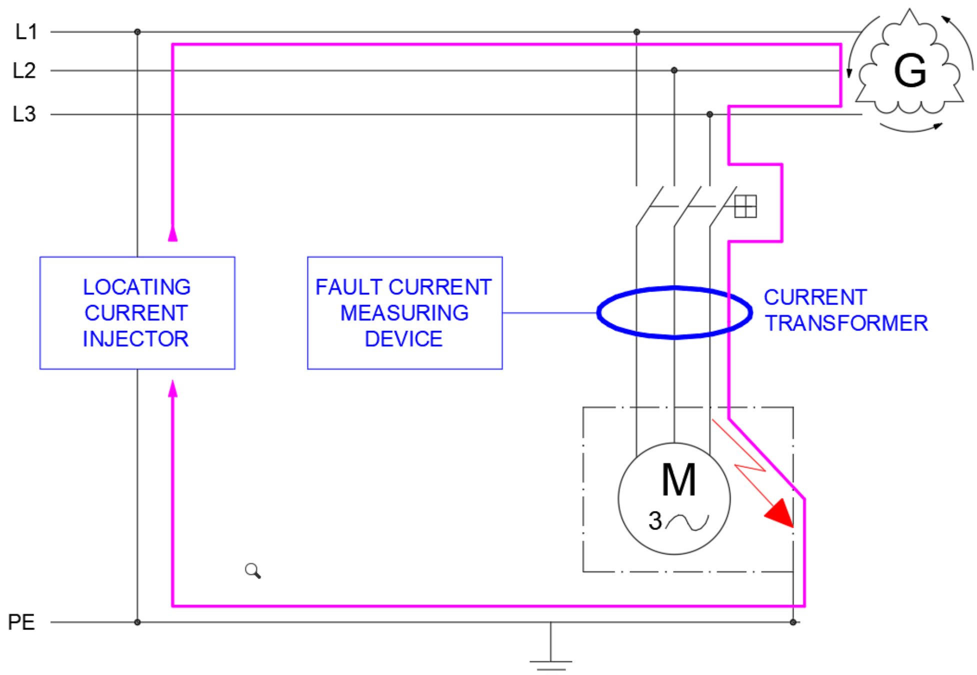


Figure 19 Insulation fault locating system principal

13.4.2 Refrigerated Container Monitoring System

Within an increasing number of integral refrigerated containers being used in maritime transport, there is also a greater need for effective ways of monitoring these containers. Using a remote monitoring system can enable the crew to react more rapidly to potential problem in event of a refrigeration unit failing. These systems can be wired systems or wireless systems. The information may be about current temperatures, any alarms that have occurred etc. Printed logs generated as a result of this exchange can effectively replace manually recorded temperature data.

13.4.2.1 Types of Remote Monitoring Systems

13.4.2.1.1 Four Wire System

In this type of wired remote monitoring system, a separate monitoring cable with four wires is used to record the status messages “Compressor running”, “Defrost” and “Temperature in range”. Three signals are provided by four-wire technology, the most important signal is undoubtedly “Temperature in range”. If this is not issued, an alert is triggered. Very simple monitoring systems can therefore only evaluate this signal. The other two signals are “Defrost” and “Compressor running”, which are status signals that are required to provide further information for the crew.

13.4.2.1.2 Power Cable Transmission System (PCT)

In this system, data is transmitted through the three-phase power supply cable of the container. This enables an unlimited amount of data to be transmitted between the container and the receiver on board the ship or on land. Since data can be exchanged in both directions, it is possible, for instance, to change the set point value of the temperature of the container from a remote location. There is a tremendous cost-saving potential offered by the option of making remote Pre-Trip Inspections (PTI) of the containers on board or in the terminal, as well as to read out data logger information after a loaded passage.

PCT system is currently available in two types: Narrowband transmission, which operates at a fixed frequency to modulate data on to the power supply system, and Wideband transmission, in which data is transmitted over a frequency spectrum.

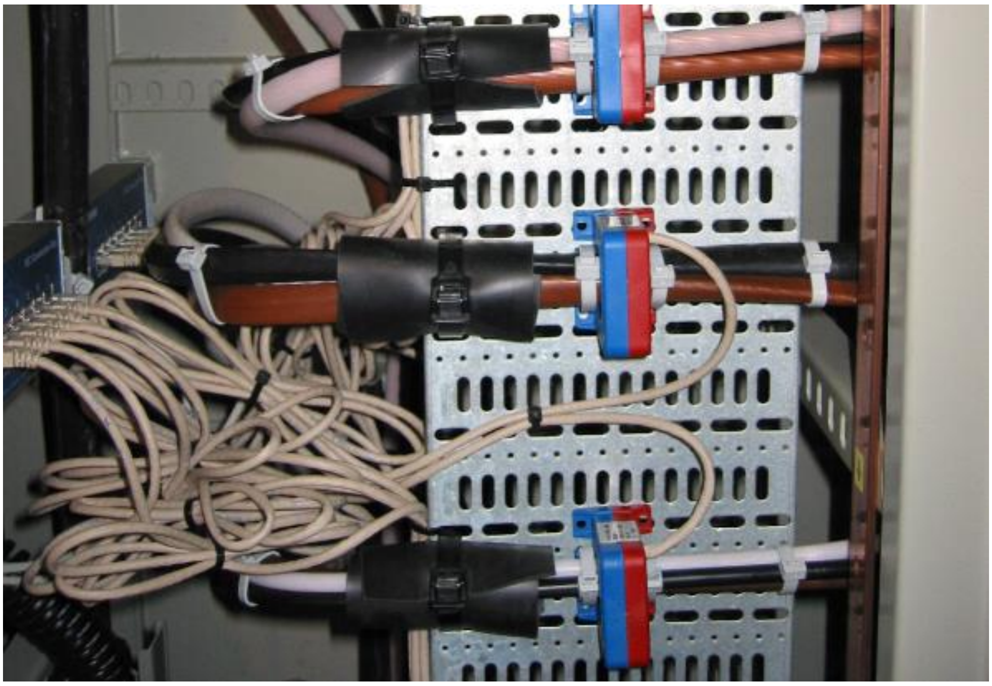


Figure 20 Example of PTC equipment installed on sockets power supply line

13.4.2.2 ISO 10368 standard (PTC)

To facilitate the use of communication between many different producers of the containers and the ship's monitoring system a standard for this communication has been agreed. Standard primarily regulates the data transmission protocol (i.e. software) and defines the minimum range of functions for remote communication devices (RCDs). These functions comprise (list not complete): Identification number of the container, current return air temperature, current supply air temperature, manufacturer/type, operating mode (Full Cool, Partial or lower capacity cool, modulated Cool, Fans only, Defrost, Heat), nominal temperature, alarms (status query), current alarms (in the order in which they occurred), product temperatures, data logger interval, power consumption, port of destination of the container, port of discharge, origin, results of the self-check (PTI).

13.4.2.3 Today`s use of PCT on reefer container

Most reefer containers (60%) are equipped with a PCT module, and there will be more in the future. All data can be monitored from computer connected to the Internet using Global Monitoring Server. The system is designed as a means of tracking goods transported in refrigerated containers. The condition of the container can be used, in the case of transport on board, as input to assess the risk of a potentially hazardous situation.

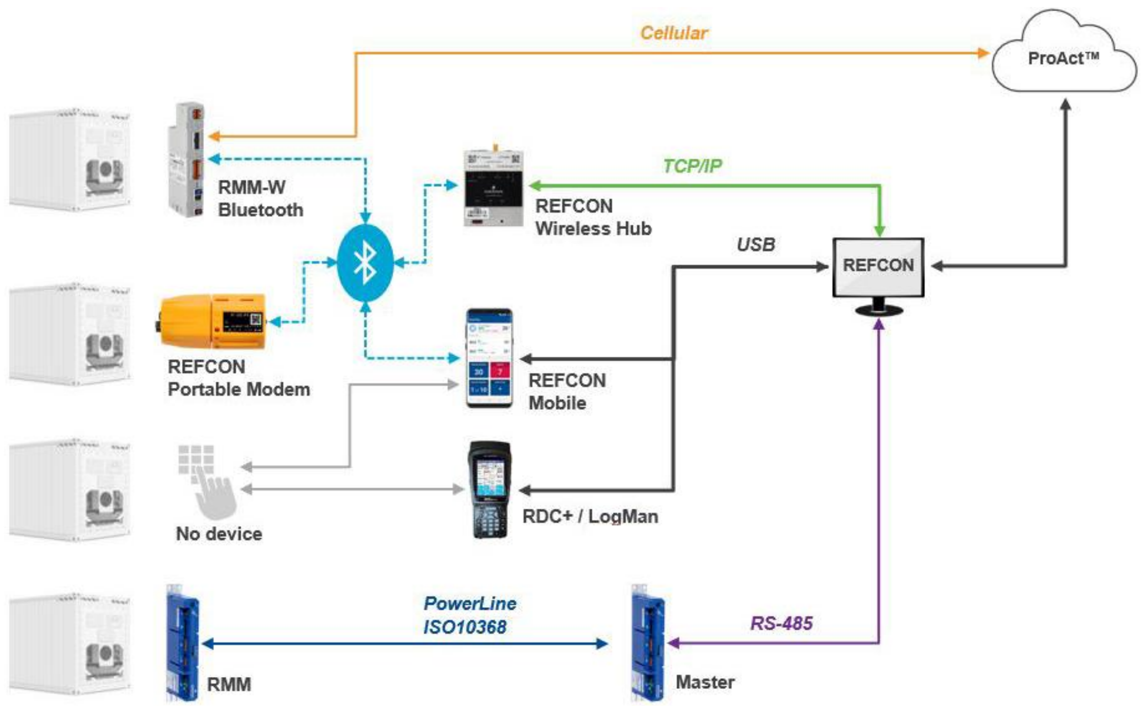


Figure 21 Use of PCT on reefer container

13.4.2.4 Miscellaneous considerations

It is not un-common that ships are lengthened by some 20-40 meters in mid ship area. This may affect cable lengths and reefer socket system characteristics.

13.5 Proposal for development

Proposals for the development of a simple and robust electric system for connection of reefer units are listed below:

- Fuses for reefer sockets should be as close to socket as possible and with correct sensitivity according to IEC standard and IK2/Ik3
- Cables to be according to IEC standard, also of shortest length and minimum 4mm2 cable size.
- Sockets with power switch to be used only
- Sign at each socket on what cable may be used (area and max length)
- Make sure that cable ends (cable shoes) are done in a proper way, not destroying threads, reducing area to less than 4 mm. In such case heat may be generated even if current is within limits.
- Measurement of short cut currents Ik2 and Ik3, and continuity
- Impedance to be measured 2/year on each socket to be compared to target value. In this way it is secured that the intended protection is provided.
- Detail inspection criteria for reefer cables must be established.
- Earth fault breakers may add safety, either per socket or in groups (example is the Megacon isopak).
- The current practice at earth faults is that those are measured and information sent to an ECR alarm, but no actions are taken.

14 Fire requirements for new deck materials - Action 8-C

Main author of the chapter: Obrad Kuzmanovic, FLOW

This chapter is giving an overview of the ship integration requirements for the Action 8-C i.e. Fire requirements for new deck materials.

14.1 Short Description of the addressed Action

The objective of the Action 8-C is to determine requirements for reaction-to-fire properties for non-regulated new materials used in surfaces of ro-ro spaces, through the following:

- Investigation of new material solutions
- Fire risk assessment and new requirements for ro-ro space surfaces definition

14.2 Design, production and operational aspects

14.2.1 Surface protection

14.2.1.1 Typical coating layouts in ro-ro spaces

Typical painting schemes in ro-ro spaces, distinguished by ship location, paint type and dry film thickness, are shown in tables below. All layouts are based on application of epoxy/polyurethane coating systems. These paint systems can be approved for use as low flame spread surface materials, not generating excessive quantities of smoke or toxic products in fire.

There are several different epoxy coatings, each one of them made to meet certain requirements during service. Epoxy coatings have some general characteristics. The most important advantages are good water resistance, good adhesion to the substrate, good chemical resistance, very good alkali resistance, great resistance to mechanical damage, high durability, temperature resistant up to 120 °C (somewhat lower/ higher for certain systems), certain systems officially approved for potable water tanks and in contact with food, high solids content/low VOC possible. Limitations are poor UV resistance – chalks in sunlight, application and curing depends on the temperature, it may be difficult to overcoat cured epoxy, short maximum over coating intervals, two-component products and therefore require good mixing and may give increased wastage, moderate resistance to acids.

Epoxy can be modified using phenol, coal tar and hydrocarbon, reinforced with glass lakes etc. to give special properties, e.g. better chemical resistance, better penetration, better water resistance, impact and abrasion resistance etc. Among the most versatile coatings is epoxy mastic, due to its very good resistance to water. Also, contain high solids content which eliminate large quantities of solvent. However, a topcoat is required when exposed to UV-light, i.e. for weather decks, as well as for decorative purpose.

Polyurethanes are mainly used as topcoats in an epoxy paint system. Polyurethane coatings can be both one-component (moisture cured) or two- component. Two-component polyurethanes are among the most versatile coating types. They fill a vital niche for high-performance applications over metal, concrete, wood and plastic. These coatings show excellent colour and gloss retention for outdoor exposures. In addition, they are resistant to chemicals and solvents. Benefits are very good weather resistance, excellent gloss durability, very good chemical resistance, very good solvent resistance, while main limitation is that it is a two-component coating and it may cause skin irritation during application.

Table 18. Ro-Ro cargo ship painting scheme 1 (for heavy cargo)

Surface area	Paint type	Dft (µm)
Weather deck , deck in open ro-ro space	Abrasion resistant epoxy	100
	Abrasion resistant epoxy	150
	Polyurethane	80
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks; Rampways under side; Hoistable deck under side	Abrasion resistant epoxy	100
	Polyurethane	80
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks – under insulation	Abrasion resistant epoxy	100
Open/closed ro-ro space: Steel decks and platforms Hoistable deck upper side (“floor”)	Abrasion resistant epoxy	100
	Abrasion resistant epoxy	150

Table 19. Ro-Ro cargo multipurpose ship painting scheme 2 (container, various cargo and vehicle carrier)

Surface area	Paint type	Dft (µm)
Weather deck	Epoxy	150
	Epoxy	100
	Polyurethane	50
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks; Rampways under side; Hoistable deck under side	Epoxy	130
	Polyurethane	50
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks – under insulation	Epoxy	85
Open/closed ro-ro space: Steel decks and platforms Hoistable deck upper side (“floor”)	Epoxy	120

Table 20. Vehicle carrier painting scheme 1

Surface area	Paint type	Dft (µm)
Weather deck	Epoxy	125
	Epoxy	125
	Polyurethane	50
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks; Rampways under side; Hoistable deck under side	Epoxy	100
	Polyurethane	50
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks – under insulation	Epoxy	100
Open/closed ro-ro space: Steel decks and platforms Hoistable deck upper side (“floor”)	Epoxy	100
	Epoxy	100

Table 21. Vehicle carrier painting scheme 2

Surface area	Paint type	Dft (µm)
Weather deck	Epoxy	125
	Epoxy	125
	Polyurethane	50
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks; Rampways under side; Hoistable deck under side	Epoxy	85
	Polyurethane	35
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks – under insulation	Epoxy	85
Open/closed ro-ro space: Steel decks and platforms Hoistable deck upper side (“floor”)	Epoxy	125

Table 22. RoPax coating painting scheme

Surface area	Paint type	Dft (µm)
Weather deck	Epoxy	150
	Polyurethane	75
	Polyurethane	75
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks; Rampways under side; Hoistable deck under side	Polyurethane	75
	Polyurethane	75
Open/closed ro-ro space: Shell, walls and bulkheads, undersides of decks – under insulation	Epoxy	100
Open/closed ro-ro space: Steel decks and platforms Hoistable deck upper side ("floor")	Epoxy	100
	Epoxy	100

14.2.1.2 Anti-skid surfaces

Anti-skid coatings are low profile skid resistant surfaces, usually applied on steel ramps and decks, which contribute to the safe and efficient loading and discharging of vehicles and pedestrian traffic in both wet and dry conditions.

Anti-skid surfaces are a selection of high-grade abrasion resistant aggregates held together with a blend of specially formulated polyurethane or epoxy resins, designed to give strength, flexibility and long-life durability.

The resin systems are fully impervious and encapsulates the steel surface to give it corrosion protection, thereby extending the service life of the steel itself.

Aggregates are available in a variety of sizes, depending on the service conditions, and should be chemically inert and to have good impact crushing, abrasion and skid resistance.

Anti-skid surfaces are preferred by drivers of vehicles, for its smoother ride, unlike the vibrations and wheel spin they experience with the traditional metal anti-skid systems. The installation of such coating can save tractor unit owners less wear and tear on their vehicles as a direct result of the removal of these two conditions. Gear boxes and tyre service life is extended, not having to deal with loss of traction.

The product offers the key features mentioned above, which were seen as particularly important to vehicle carrier operators for the speedy, safe and efficient loading and discharging of their car carrying operations. There are quite a number of anti-skid coats and aggregates manufacturers, all of them already tested and certified according to IMO Resolution MSC 61(67): Annex 1, Part 5 Surface Flammability & Part 2 Smoke and Toxicity .

Figure 22. Anti-skid surface example

14.2.2 Ro-ro space structural material

Steel is the conventional and benchmark material used in shipbuilding, especially on larger vessels such as vehicle carriers, ro-ro cargo and ro-pax vessels. However, new material and design solutions are needed to achieve added values, such as reduced fuel consumption and increased payload. Unfortunately, despite numerous advantages, lightweight materials are still rarely used in large vessels' construction. This is mainly due to the SOLAS regulations issued by the International Maritime Organization (IMO), which required that commercial ships are built in steel until the MSC/Circ. 1002 was issued in 2002 giving the possibility for alternative designs. This regulation mandates a risk analysis to be performed, showing that the alternative design and construction is equivalent to steel. This process is long, expensive and the final decision of relevant authorities could still be negative. Still, ship owners, operators and builders are seeking solutions for improved sustainability, including lighter weight to reduce fuel use, greenhouse gas emissions and payload increase. Moreover, there is certain limited use of lightweight materials in ro-ro vessel's space, through implementation of composite materials, aluminium alloys and plywood.

14.2.2.1 Composite materials

Composite materials have proven themselves to be an attractive material choice when it comes to lightweight and freedom of design. Lightweight design by fibre reinforced composites has only been used in ro-ro cargo space in one case so far, the ULJANIK built vehicle carrier as first extensive shipping industry application of sandwich composites. Challenges encountered during implementation of composite materials were how to achieve required strength and stiffness, fire safety equivalent to steel and related costs [16].

The structure arrangement consists of a steel supporting grillage and composite sandwich panels. In general, the panels have GRP (Glass Reinforced Polymer) laminates and PVC (Polyvinyl Chloride) core, manufactured by vacuum infusion. The composite panel flexible connection to the supporting structure is designed. The panel system includes corresponding joints and outfitting elements (lashing devices, lifting elements etc.). A total of 1043 composite panels, of abt. 11 square meter each, have been arranged in current ship designs on relevant three car decks.

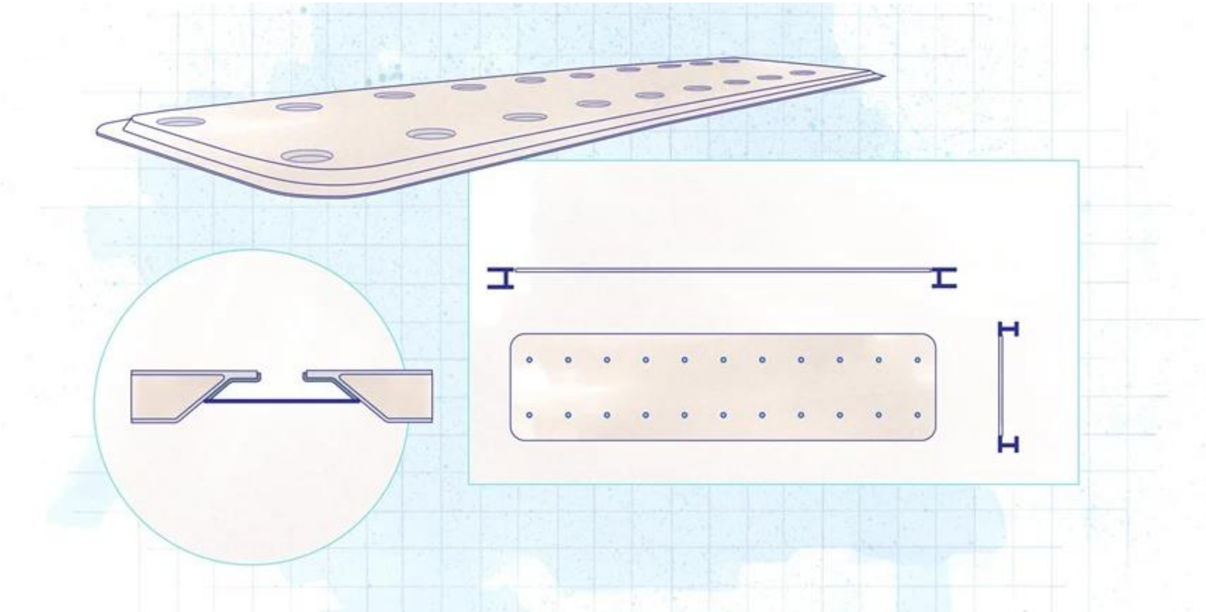


Figure 23. Car deck composite panel - sketch

Although, in this particular case, the ship does meet SOLAS fire safety requirements independent of the composite panels, a fire safety assessment was performed according to MSC/Circ. 1002 to demonstrate that the alternative design (with composite decks) achieves fire safety equal to that of the conventional design (with steel decks). The fire safety assessment, conducted by RISE Fire Research AS (Boras, Sweden), revealed the composite deck disadvantages that included the potential for greater linear (same deck) fire growth rate, more compromised panel structural integrity, and toxic smoke due to hydrochloride creation from burning PVC. But the panels also demonstrated delayed deck-to-deck fire spread, due to the panels' insulating effects and the closed lashing holes. Additionally, the composite panels, unlike steel plates, insulate crew members from the heat of a below-deck fire, so escape routes can cross panels on overhead decks.

To make composite decks economically feasible, thorough investigation must be performed to select optimal sandwich materials and fabrication process that results in a production cost equal or at least similar to that of traditional steel decks. For the panel laminates, polyester, vinyl ester and epoxy resin systems were considered. Polyester resin was chosen for its cost and its properties favourable to vacuum infusion, and the panel fabrication method, also chosen for its cost-efficiency. Further, using well-established materials and simple geometries in the floor panels enabled shorter lead times as well as improved manufacturing reliability and quality.

Figure 24. Car deck composite panels

Because the floor panels reduce weight in the ship's uppermost decks, weight savings are doubly beneficial. First, the three composite decks are 25% lighter than three steel decks, saving 230 tons. Second, the lighter upper decks lower the ship's vertical centre of gravity (VCG). Therefore, less ballast is needed to ensure the ship's stability. Alternatively, for the same fuel consumption as a vehicle carrier with all-steel decks, the vessel may increase its payload by as much as 805 tons. The composite decks also will reduce maintenance costs because they do not corrode. Environmental benefits from the fuel savings include reduced fuel oil consumption and carbon dioxide emissions for 4.5 % or 2.1 t/day of fuel oil.

A step forward towards improving fire properties, reducing weight, production cost and lead time will be investigating new materials and technologies as well as replacing steel supporting structure with composites. Further development on similar lightweight structures is continued by FLOW ship design team within the EU funded project RAMSSES, where pultruded FRP are investigated.

14.2.2.2 Wood

Lightweight liftable and hoistable car deck panels have been developed, which incorporate plywood in their construction to reduce their weight considerably compared with steel equivalents. The panels can accommodate car lashing fittings. The individual panel configuration options give operator the flexibility to adjust to different cargo on different routes. The car deck panels feature a lightweight open beam construction with a plywood top plate to minimize their weight and therefore their impact on ship stability. The developed lashing profile is also a very special concept. The lashing is not attached to the plywood panel itself, but to the steel secondary stiffeners, which also act as a support for the plywood panels. This patented lightweight car deck concept meets environmental protection in several ways:

- Compared with steel the panels have a lower cost and lower weight with the same durability and lifetime.
- Lighter decks improve vessel efficiency in terms of payload and flexibility of operations.
- Lighter decks and ships allow increased speed or reduced fuel consumption.
- Stability benefits are gained by reducing weight high up in the vessel's structure.

Figure 25. Plywood car deck panels

14.2.2.3 Aluminum

Aluminum alloys for use in marine applications are normally of the 5xxx series (with magnesium as alloying element) or, for locations such as decks that are not in direct, continuous contact with sea water, the 6xxx series (with magnesium and silicon). Plates are normally strain hardened (cold worked), giving an "H" temper designation. Stiffeners and deck plating are generally extruded. Wrought aluminum alloys have a high strength/weight ratio compared to steel. Aluminum alloy structures generally have higher stiffness than corresponding FRP structures. Many grades are

weldable, and many are also extrudable. Aluminum alloys, if chosen correctly, have a good corrosion resistance. The main disadvantage of aluminum is the severe softening of the heat affected zone (HAZ) that occurs during welding. This reduces both the static strength and the fatigue life. Aluminum alloys are also relatively expensive to weld. The combination of a high required heat input and a high coefficient of expansion leads to large distortions and shrinkage during welding. If the wrong alloy is selected for a given purpose, corrosion resistance may be poor. Aluminum alloys have a fairly low melting point (around 650ºC) and they soften at temperatures considerably below this, so that aluminum structures generally require extensive fire insulation. The tearing resistance of aluminum is relatively poor; however, this disadvantage is not reflected in the required scantlings of ships because the prescribed damaged stability cases take no account of the difference in tearing resistance of the various materials.

However, there has been no aluminum alloys applications as structural material in ro-ro space, (HSC are not considered) due to too expensive design, despite their widespread use in outfitting equipment (railings, smaller ramps, gangways etc.)

14.2.3 Insulation

The purpose of passive fire protection is to raise the fire resistance of the structure, to protect the structure against the effects of fire, to reduce the fire spread through secondary ignition, to limit the movement of flame and smoke and to minimize the danger of fire-induced collapse or structural distortion.

Passive fire protection in marine industry is traditionally based on glass or mineral wool (stone wool) products, which cannot burn, and which can stand temperatures up to 1000°C without melting. The fibers are usually bonded with appropriate binding agent, which evaporates on much lower temperatures, generating smoke in a fire. However, the fibers remain intact thanks to their inbuilt cohesiveness and layering, ensuring that the material will retain its rigidity and protect the material beneath it from fire. Mineral or glass wool usually come in form of blankets or slabs, with or without protective covering, such as aluminum foils, glass cloth or similar, for areas exposed to weather or potential physical damage. The insulation is typically held in place by steel pins of appropriate diameter. There are large number of marine insulation manufacturers on the worlds market.

The appropriate fire class division (A, B or others) is always obtained with a combination of thickness and characteristics of insulating material as well as a type of material being insulated.

14.2.3.1 Ceramic fiber insulation

There are also insulations based on thermal and pure ceramics fibers, a range of advanced fire protection materials. Ceramic fibers are usually a combination of high purity raw materials like aluminum powder, pure silica sand and zircon sand. It is usually applied on offshore objects, due to very good thermal resistance (1200°C for extended time period – hydrocarbon fire protection). These materials do not contain any chemical binder and therefore does not generate smoke in a fire, it is a non-combustible and non-toxic material. Provides not only fire insulation, but also excellent thermal and acoustic insulation. Moreover, thermal ceramics is lightweight material, with typical weight saving of 30% compared to traditional materials but the investment cost is higher compared to the cost of conventional glass or mineral wool products applications. Finally, it contains low bio-persistence fibers, so is exonerated from any carcinogenic classifications.

14.2.3.2 Spray-on insulation

Installing traditional insulation on marine structures is labor intensive and thus expensive, while insulation's long-term performance is typically reduced or greatly compromised by wet working conditions or mechanical damage. Conventional techniques with prefabricated insulation elements have a number of built-in limitations; weak points that can seriously impair the efficiency and economies of fire protective shield. The total cost for a completely insulated surface using spray-on insulation should therefore be lower than with conventional techniques. It also eliminates the need for mechanical fasteners and manual cutting of pre-fabricated standard sized insulation elements, which results in around 20-30% of wasted material. Moreover, the insulation layer is seamless as there is no gaps or cracks like in joints between pre-fabricated elements. The spray-on insulation is easily applied onto the flat, curved, uneven surfaces, inside ducts, around corners and on already installed equipment or structures, electrical or piping fixtures.

Figure 26. Sprayed-on insulation

Basically, it is a self-adhesive glass or stone wool (depending on level of insulation needed), sprayed directly onto a surface. It is used in combination with a waterborne two-component binder system, which is entirely free of additives such as solvents, asbestos, cement or fusible silicates. If fire protection is needed, the fibers are manufactured from diabase or basalt, to withstand more than 1100°C. The surface can be coated with aluminum foil or sprayed with vinyl coating, fire retardant, nontoxic and smokeless surface, which can be used where original insulation is exposed to high-pressure cleaning, oil vapor or similar, such as storages, engine room, machinery room etc. If applied in ro-ro spaces, the surface is usually protected with metallic sheets.

This type of insulation requires special equipment, such as special coating machine and spray gun with 3-way nozzle. Spray-on insulation must always be applied by a specially trained and licensed applicator with documented skills and experience, to ensure the right quality of the insulation and that the insulation complies with the certificates issued by relevant authority.

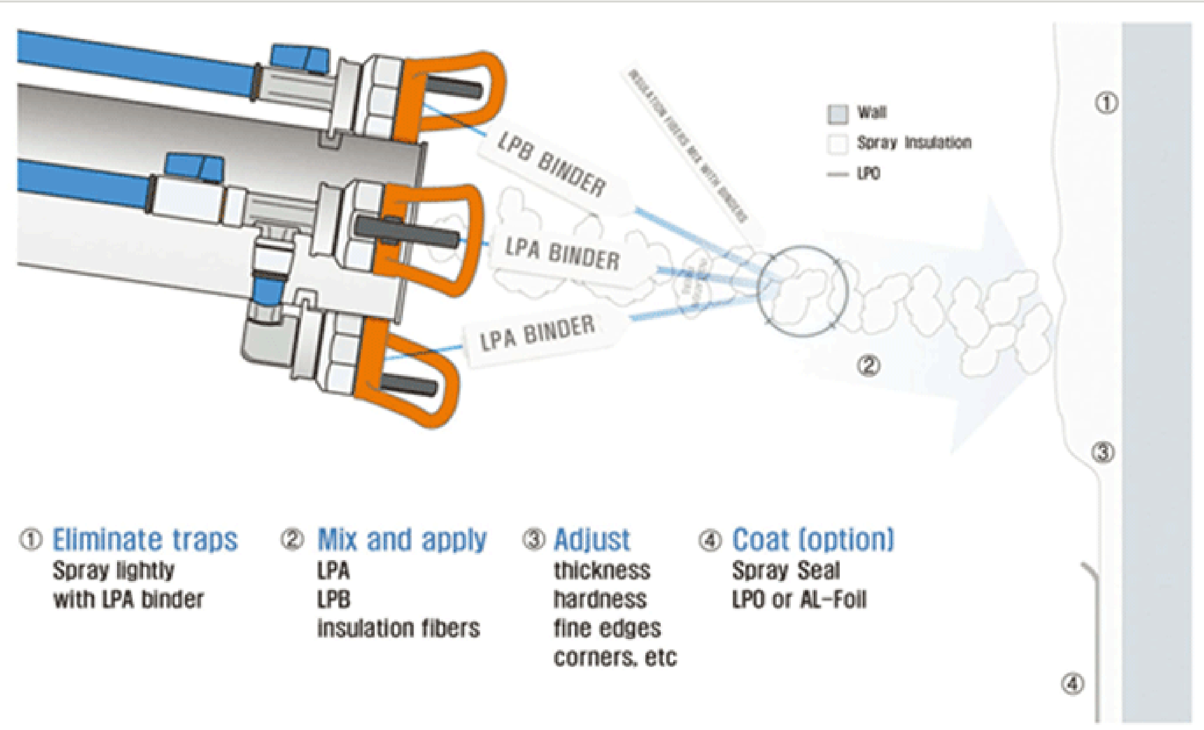


Figure 27. Spray-gun with 3-way nozzle

This particular spray-on insulation system is very successful in the South Korean market and shipyards, resulting in a large number of major contracts with world leading ship owners and operators.

14.3 Environmental aspects

First of all, innovative materials should have as less environmentally harmful and toxic substances as possible, as well as their ignition products (burnt remnants, fumes). Further, it should be lighter than conventional solutions, thus reducing the fuel consumption and connected Greenhouse gases emissions. Finally, new solutions should be maintenance friendly, which shall also be beneficial for environmental protection.

14.4 Proposal for development and restrictions

There are several interesting solutions which are already well known in the civil and/or offshore objects and which could be also widely used in the marine environment, in particular for ro-ro cargo spaces. Intumescent coatings, already widely used in offshore oil and gas industry for more than 20 years, could be one of the potential passive fire protection means as a replacement of the conventional insulation or to be used on critical points, such as gaps at ro-ro ramps/hatches, etc. These fire-retardant coatings are active only in a case of fire or temperature rise, undergoing a chemical reaction that results in expansion to several times its initial volume, forming a fire stable and insulating char. This could be promising material as ro-ro cargo space gastight deck coatings, despite poor thermal and acoustic insulation.

A step forward towards improving fire properties and reducing weight will be investigating new materials and technologies for structural application on ro-ro ships, as to replace conventional steel structure arrangement.

Several composite components and combinations may be considered, including core type (known materials as PVC, PET, Balsa, and other cores recently available on the market or under development), fibres (glass, carbon, basalt, hybrid, etc.) and composite products with improved fire properties such as multiaxial fabric with integrated fire protection for structural parts with a fire-retardant surface layer.

Production technology (vacuum infusion, pultrusion, prepreg, etc.) may have effect on the composite component fire properties (mainly due to the amount of resin) as well as on cost and production lead time. Further, this may also be considered.

Innovative types of composite materials (resins, cores, fibres, production technologies) are currently under development at EU funded R&D projects RAMSSES (CMT, BV, RISE and FLOW part of the project consortium) and FIBRESHIP (BV, VTT and CIMNE part of the project consortium).

15 Means for detection on weather deck - Action 9-A

Main author of the chapter: Sif Lundsvig, DFDS

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 9-A i.e. Means for detection on weather deck.

15.1 Short Description of the addressed Action

The objective of the Action 9-A is to develop, demonstrate and evaluate in full-scale means for quick and reliable detection on weather deck, through the following:

- Definition of conditions for detection on weather deck
- Development of relevant weather deck detection solutions
- Laboratory-scale testing of weather deck detection technologies
- Large scale validation of selected weather deck fire detection solutions

15.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

15.2.1 General

15.2.1.1 Scope

This section aims at giving an overview of the requirements applicable to ro-ro spaces regarding action 9-A, i.e. "Detection on weather deck".

15.2.1.2 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships. As an indication, FSS Code Chapter 9, dedicated to fixed fire detection systems was fully reviewed through MSC.311(88) and applies to ships the keel of which was laid after 01/07/2012. However, only few significant changes in the regulations were identified over the last 40 years.

A brief summary of the main regulation changes related to Detection on weather decks is provided in Table 23 with a particular focus on regulations relevant to Action 9-A.

Table 23. Summary of regulation changes

Regulation change	Application date	Adoption date	Summary
SOLAS 74	1980[12]	1974	Introduces the principle of horizontal fire zone for ro-ro spaces / special category spaces with: - Structural fire protection - Fixed fire extinguishing system ("drencher" type) - Fixed fire detection system
MSC.311(88)	2012	2010	Revision of FSS Code Ch.9

[12] It is to be noted that the concept of horizontal fire zone and associated safety measures has actually been introduced in SOLAS 60 part H as per IMO resolution A.122(V) dated October 1967. However, the circular was never made mandatory and Part H was therefore only applied on a voluntary basis until SOLAS 74 came into force. Compliance with Part H is formally recognized to be equivalent with SOLAS 74.

The review is mainly based on the documents listed in Table 24.

Table 24. List of documents used for the review of regulations for Detection on weather decks

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1242 – Guidelines for approval of fixed fire detection and fire alarm systems for cabin balconies
	MSC.1/Circ.1615 – Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	UI SC73 rev.2 – Nov. 2005 "Fire protection of weather decks"
Flag Administration Rules	N/A

15.2.2 Requirements

15.2.2.1 General

This section describes the general requirements related to detection on weather deck and provides the associated reference(s) in the regulatory texts.

SOLAS II-2/20.4.1 requires a fixed fire detection and fire alarm system to be fitted in all ro-ro spaces.

However, it is widely accepted that no fixed fire detection and fire alarm system is required on weather decks used for the carriage of vehicle with fuel in their tanks as per IACS interpretation UI SC73.

MSC.1/Circ.1615 proposes to install a fire detection system on weather decks for new ships:

> "2.4 Fire detection on weather decks
>
> A fixed fire detection and fire alarm system should be provided for weather decks intended for the carriage of vehicles. The fixed fire detection system should be capable of rapidly detecting the onset of fire on the weather deck. The type of detectors, spacing, and location should be to the satisfaction of the Administration, taking into account the effects of weather, cargo obstruction and other relevant factors. Different settings may be used for specific operation sequences, such as during loading or unloading and during voyage, in order to reduce the false alarms."

It is to be noted however that MSC.1/Circ.1615 is a mere guideline, therefore applicable only on a voluntary basis, and targets only passenger ships. In addition, no detailed technical standard is currently available to specify which kind of fire detection would be effective on weather decks and which kind of fire detection system could reasonably be installed on weather decks.

15.2.3 Other regulations

As detailed in 15.2.2, fixed fire detection systems shall be provided in closed and open ro-ro spaces of ro-ro passenger ships, but not on weather decks. This section lists existing regulations or documentation not directly applicable to systems in ro-ro spaces, but which could be used in order to propose solutions that might be relevant for Action 9-A (i.e. Fixed fire detection systems for outside areas)

15.2.3.1 Fire detection for cabin balconies

Fire detection is required on passenger ship cabin balconies unless the furniture and furnishings are of restricted fire risk as a result of SOLAS[13] 2006 amendments (SOLAS II-2/7.10). Since they are installed in non-enclosed spaces, these systems can be a useful reference with respect to fire detection in open ro-ro space and on weather decks.

Fire detection systems on cabin balconies are to be in line with MSC.1/Circ.1242. Basically, these guidelines are very close to chapter 9 of the FSS Code (see IR04.4 for more detail). The following requirements can be stressed, since they are related to adaptation to an outdoor location:

> "2.3 The system should be capable of fire detection on cabin balconies with expected wind conditions while the vessel is underway
>
> 2.4 […] External components should additionally be designed to withstand sun irradiation, ultraviolet exposure, water ingress and corrosion normally encountered on open deck areas.
>
> 2.6 The location and spacing of the detectors should be within the limits tested."

For practical purposes, fire detection systems installed on cabin balconies rely on flame detection technology, since it is not affected by wind as heat or smoke detectors would.

15.2.3.2 Fire detection on covered mooring decks

Following a fire on the aft mooring deck of the Grandeur of Seas, CLIA recommends to its members to implement a fixed fire detection system and a fixed fire extinguishing system on covered mooring decks. Flame and smoke sensor technology integrated into CCTV systems are deemed effective as fire detection systems for covered mooring decks, and more adequate than conventional fire/smoke detection systems.

15.3 Operational aspects

Fire detection on weather decks, are mainly depending on manual detection. This can be the OOW looking out over the deck while navigating the ship, or it can be fire-rounds made by a deckhand or other crew seeing to the ship during workhours, or mandatory fire rounds for ro-pax vessels.

Often vessels have CCTV surveying the weather deck, although this is as mentioned in Chapter 16 not primarily for fire detection.

This means that it is approved according to regulations to not have automatic means of fire detection on the weather deck. If manual inspection is the main way of fire detection, it results in little attention played to the aft weather deck, as it, unlike the foredeck does not have the OOW looking out over the deck as a natural part of their job. It also results in a non-systematic detection, that might lead to late detection as visible signs of fire are the main signs of alert.

Some vessels have optical heat detection cameras installed looking out over the weather deck. This is also not a SOLAS or class requirement. Due to the length of some open weather decks, cameras cannot necessarily keep track of an entire deck, if they are placed on the superstructure of the ship. On the other hand, they need to be placed high to have visibility of the deck, protected from weather and in

[13] See Res. MSC.216(82).

such a way that they can be serviced when needed, and this limits how widely application of heat detection cameras can be applied, unless some other way of installation is found.

For ro-ro ships trailers can sometimes be placed so close together that access on the deck is limited in some areas. This is not only the case for weather decks, but since the means of fire detection on weather decks primarily are manual inspections, it can prove a safety issue on these deck types.

In very bad weather the weather decks can be closed for access, cutting of the manual inspections, and possibility for manual firefighting due to safety concerns for the crew doing the inspections.

The weather deck also carries the dangerous cargo, so there is reason to argue that these decks that have the least surveillance are the ones that need higher safety standards the most.

However, since the weather decks are the place to store the dangerous cargo, it is also potentially high-income slots for trailers, and a fire detection solution that limits the space on these decks, will hurt the income of the shipping companies. Motivation for such solutions that limits the cargo space are therefore minimal.

15.4 Design and production aspects

A system that covers the weather deck should not only be weather resistant, but also not have an increasing amount of false alarm when exposed to saltwater spray, dirt or other and should be able to function with a minimum of cleaning of sensor parts.

The system must function under harsh weather conditions. Including ice accretion, saltwater spray, fog, direct sun etc.

As per definition of weather deck the system must be designed so that the limited superstructure (if any) is enough for installation. It would be possible to design a structure, such as a pole for placing of cameras, however vibrations and weather exposure must be taken into account, and it can under no circumstances be placed so that it endangers cargo operations by being a hindrance to the truckdrivers or tugmasters.

15.5 Proposal for development and restrictions

DFDS has a pilot project together with UPTEKO, to see if an onboard drone can be applied for automatic fire detection. The idea is, that the drone using heat scanners can detect even a small rise in temperature on trailers placed on the weather deck, thereby warning the crew early on. The drone should be able to fly and dock itself. Maintenance of one drone should then be easier to provide than for a number of heat detection cameras needed to cover the same area. Such full-automatic fire round solutions are from DFDS perspective seen as a smart way forward, providing they are reliable and cost efficient.

15.5.1 Ongoing work at Stena

Reference to pilot installation of ALPHATRON IR cameras on Stena Transit/Transporter, see Figure 28. On Stena Jutlandica a CONSILIUM optical flame detection system was installed for testing. A FIKE smoke detection system was tested on Stena Scandinavia. Also other optical systems have been investigated. More information available on request from Stena.

Proven solution

Several recent total losses of RoRo ships with open ro-ro spaces have stressed the need for investigating more efficient detection in open RoRo spaces and weather decks. The AlphaHeatDetectionSystem was extensively tested with different fire scenarios to challenge the system, taking into account the effects of ventilation, weather and other relevant factors. The test carried out on the Stena Scandinavica and witnessed by Class Society Bureau Veritas Marine and Offshore and RISE Fire Research AS, was concluded with positive results, reflecting the system is able to more rapidly detect heat sources compared to common smoke detectors.

Customer case Stena

Peter van de Wardt, Senior Master on the RoRo Stena Transporter shares his experience about the development, installation, testing and operation of the AlphaHeatDetectionCam. "Weather decks on RoRo and Ropax have no fire detectors. Fires onboard ships can be handled by ship crews only on early detection and prompt action" explains Peter van de Wardt. For Stena Line, this was a challenge to solve. They contacted Alphatron Marine for a solution. At the time there was no product on the shelf but Alphatron Marine was willing to think with us for a solution. From this point, we started a 1,5-year cooperation project and came with a unique innovative product, the AlphaHeatDetectionSystem.

Peter continues: "During these 1,5 years many challenges were met. Cable runs (cameras, supplies and internet connections) were done by the crew. For many months we did collect data and met our first big challenge: reflection from the sun. It took a long time of engineering writing new software and collecting data again. In the meantime, we did startup another project: heat cameras on enclosed decks. Here reflection will be your friend. Also, a live trial was held onboard Stena Scandinavica witnessed by the authorities which was very successful".

Sister ship Stena Transit is now also equipped with the AlphaHeatDetectionSystem on the weather deck.

"It is an innovative project which needed a lot of time and investment of both parties. The result is very good with high potential. It did meet our expectations", concludes Peter van de Wardt.

Figure 28. – Stena Transit/Transporter - Alpha Heat Detection System

16 New means for fire detection in closed and open ro-ro spaces - Action 9-B

Main author of the chapter: Sif Lundsvig, DFDS

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 9-B i.e. New means for fire detection in closed and open ro-ro spaces.

16.1 Short Description of the addressed Action

The objective of the Action 9-A is to develop, demonstrate and evaluate in full-scale alternative and complementing means for quick and reliable detection on closed and open ro-ro spaces, through the following:

- Definition of conditions for detection in open and closed ro-ro spaces
- Development of relevant technologies for detection in open and closed ro-ro spaces
- Laboratory-scale testing of new open and closed ro-ro space detection technologies
- CFD simulations of fire detection in closed and open ro-ro spaces
- Large scale validation of selected fire detection solutions for closed an open ro-ro spaces

16.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

16.2.1 General

16.2.1.1 Scope

This section aims at giving an overview of the requirements applicable to ro-ro spaces regarding action 9-B, i.e. “Detection in closed and open ro-ro spaces”.

16.2.1.2 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships. As an indication, FSS Code Chapter 9, dedicated to fixed fire detection systems was fully reviewed through MSC.311(88) and applies to ships the keel of which was laid after 01/07/2012. However, only few significant changes in the regulations were identified over the last 40 years.

A brief summary of the main regulation changes related to Detection in closed and open ro-ro spaces is provided in

Table 25 with a particular focus on regulations relevant to Action 9-B.

Table 25. Summary of regulation changes

Regulation change	Application date	Adoption date	Summary
SOLAS 74	1980[14]	1974	Introduces the principle of horizontal fire zone for ro-ro spaces / special category spaces with: - Structural fire protection - Fixed fire extinguishing system ("drencher" type) - Fixed fire detection system
MSC.1/Circ.1272	2008	-	Allows fixed water-mist fire-extinguishing systems Allows automatic release associated with some requirements related to fire detection
MSC.217(82)	2010	2006	Requires addressable fixed fire detection and fire alarm systems on passenger ships
MSC.311(88)	2012	2010	Revision of FSS Code Ch.9

The review is mainly based on the documents listed in Table 26.

[14] It is to be noted that the concept of horizontal fire zone and associated safety measures has actually been introduced in SOLAS 60 part H as per IMO resolution A.122(V) dated October 1967. However, the circular was never made mandatory and Part H was therefore only applied on a voluntary basis until SOLAS 74 came into force. Compliance with Part H is formally recognized to be equivalent with SOLAS 74.

Table 26. List of documents used for the review of regulations for Detection in closed and open ro-ro spaces

IMO Documents	SOLAS Convention, as amended
	Fire Safety Systems (FSS) Code, as amended in 2017
	MSC/Circ.1035 – Guidelines for the use and installation of detectors equivalent to smoke detectors
	MSC.1/Circ.1242 – Guidelines for approval of fixed fire detection and fire alarm systems for cabin balconies
	MSC.1/Circ.1369 – Interim explanatory notes for the assessment of passenger ship systems' capabilities after a fire or flooding casualty
	MSC.1/Circ.1430 – Revised guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces, May 31, 2012
	MSC.1/Circ.1437 – Unified interpretation of SOLAS II-2/21.4
	MSC.1/Circ.1615 – Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	UI SC35 rev.3 – July 2013 "Fixed Fire Detection and Fire Alarm System"
	UI SC73 rev.2 – Nov. 2005 "Fire protection of weather decks"
	UI SC117 rev.2 – Nov. 2005 "Fire detection system with remotely and individually identifiable detectors"
	UR E22 rev.2 – June 2016 "On Board Use and Application of Computer based systems"
	BV Rules for Steel Ship (NR467), as amended in January 2018
	BV NR598 "Implementation of Safe Return to Port and Orderly Evacuation" dd. January 2016
	DNVGL Rules for the Classification of Ships, January 2017
	LR Rules and Regulations for the Classification of Ships, July 2016
	NKK Rules for the Survey and construction of Steel Ships, June 2016
Flag Administration Rules	MMF (French Flag Administration) Division 221 "Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage", 28/12/17 edition
	US Coast Guard Code of Federal Regulations (CFR) 46, 2019 online edition
	Swedish Transport Agency "Comments and interpretations by the Swedish Transport Agency regarding IMO Conventions", version 03 dd.15/05/2017
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

16.2.2 Requirements

16.2.2.1 General

This section describes the general requirements related to Detection in closed and open ro-ro spaces, such as different types of systems required by the regulations and provides the associated reference(s) in the regulatory texts.

SOLAS II-2/20.4.1 requires a fixed fire detection and fire alarm system to be fitted in all ro-ro spaces.

It is widely accepted however that no fixed fire detection and fire alarm system is required on weather decks used for the carriage of vehicle with fuel in their tanks as per IACS interpretation UI SC73.

It is to be noted that fire detection is required on open ro-ro spaces (although some discussion on this point regularly arises at shipbuilding phase).

16.2.2.1.1 Type of fixed fire detection system

SOLAS II-2/20.4.1 requires a standard fixed fire detection and alarm system in line with FSS Code requirements.

16.2.2.1.1.1 Passenger ships

As a preliminary remark, it should be noted that, in special category spaces – i.e. ro-ro spaces where passengers can have access , the fixed fire detection system is allowed to be replaced by "an efficient fire patrol system […] maintained by a continuous fire watch at all times during the voyage" as per SOLAS II-2/20.4.3.1. It is to be noted that some Flag States require a fixed fire detection system, independently of the existence of continuous fire watch (e.g. French Flag) and this option is further questioned in the ongoing IMO work on fire safety on ro-ro passenger ships.

Unless an efficient continuous fire watch is performed however, a fixed fire alarm and fire detection system is required open and closed ro-ro spaces of passenger ships and it is worth noting that sample extraction smoke detection systems are not allowed on passenger ships vehicle spaces since SOLAS II-2/20.4.2 prohibits such systems[15] in "*open ro-ro spaces, open vehicle spaces and special category spaces*".

In addition, on passenger ships constructed in or after 2010, the system is to be addressable i.e. capable of identifying remotely and individually each detector and manually operated call point (FSS Code Ch. 9 §2.1.7). Before 2010, the fixed fire detection system was required to be divided into sections, and to be able to indicate in which section a detector has been activated.

MSC.1/Circ.1615 further proposes:

> "2.1 Addressable fixed fire detection and alarm systems
>
> 2.1.1 For ships built before July 2010, it is recommended that a fixed fire detection and alarm system with individually addressable detectors be considered to replace existing systems in ro-ro spaces and special category spaces.
>
> 2.1.2 If a fixed water-based deluge system is used for ro-ro spaces and special category spaces then a fire detection and alarm system addressable to the same sections of the deluge systems should be arranged."

It is to be noted however that MSC.1/Circ.1615 is a mere guideline, therefore applicable only on a voluntary basis, and targets only passenger ships.

16.2.2.1.1.2 Cargo ships

SOLAS II-2/20.4.2 allows sample extraction smoke detection systems except in "open ro-ro spaces, open vehicle spaces" as an alternative for the fixed fire detection and fire alarm system required in SOLAS II-2/20.4.1. The systems shall be compliant with the requirements with the FSS Code [FSS Code Ch. 10].

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[15] Sample extraction smoke systems have been prohibited in SOLAS 1989 amendments (MSC.13(57)), applicable to ships constructed on or after 1 February 1992. As far as BV knows, this was a consequence of the bad service conditions observed on ro-ro ships for such systems (pipe ageing and corrosion) which usually had a common steel piping with the gas fire-extinguishing system.

16.2.2.2 Fixed fire detection and fire alarm systems - Performance

This section describes the performance expected from the different systems as detailed in the standards and regulations. Therefore, this section focuses on fixed fire detection and fire alarm systems as described in FSS Code Chapter 9.

16.2.2.2.1 General

SOLAS II-2/20.4.1 sets the following general performance requirements:

- "The fixed fire detection system shall be capable of rapidly detecting the onset of fire"
- "After being installed, the system shall be tested under normal ventilation conditions and shall give an overall response time to the satisfaction of the Administration"

Common practice as per BV field experience is to perform this test using a smoke generator. A usual criterion is that the fire detection system is to be activated within 3 minutes.

A similar criterion can be found in French Flag Regulations (div 221-II-2/7.4) and BV Rules (NR467 Pt F, Ch. 3, Sec. 1 [3.2.15]) for unattended machinery spaces fire detection.

FSS Code Ch. 9 §2.1.2 lists the following main functionalities for the fire detection system:

- "control and monitor input signals from all connected fire and smoke detectors and manual call points;
- provide output signals to the navigation bridge, continuously manned central control station or onboard safety centre to notify the crew of fire and fault conditions;
- monitor power supplies and circuits necessary for the operation of the system for loss of power and fault conditions; and
- *the system may be arranged with output signals to other fire safety systems*" (communication, alarm and public address systems, ventilation, fire doors and fire dampers, fire extinguishing and systems supporting evacuation such as Low Location Lighting (LLL))

16.2.2.2.2 Maintenance

In-service testing and proper maintenance are required in FSS Ch. 9 §2.5.2, SOLAS II-2/7.3 & SOLAS II-2/14.2.2.

16.2.2.2.3 Alarm

The activation of any detector or manually operated call point is to initiate a visual and audible alarm at each indicating unit, i.e. at least at the safety centre and at the navigation bridge.

After 2 minutes, if the alarm has not been acknowledged, an audible fire alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of category A (FSS Ch. 9 §2.5.1).

In addition, a special alarm is required by SOLAS II-2/7.9.4, in order to allow summoning the crew from the navigation bridge or safety centre.

Sound pressure levels are given in FSS Ch. 9 §2.5.1.9.

16.2.2.2.4 Information exchange and interaction with other systems

In general, FSS Code Ch. 9 §2.1.3 limits the interaction of the fire detection system with other systems to output signals sent to other safety systems. However, it allows the fire detection system to be connected to a decision management system[16] provided this decision management system can be disconnected without impact on the required functionalities for the fire detection system. It is also required that malfunction of the decision management system will not propagate into the fire detection system.

IACS UR E22 reckons the fire detection system as a category III, i.e. in case of fire, its failure could "*immediately lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment*". It therefore sets a number of requirements for the system supporting software development and testing process, aiming at ensuring its operational reliability.

In addition, MSC.1/Circ.1430 makes it clear that the fire detection system may control the release of the water-based fixed fire-fighting system in the vehicle space, in case the fixed fire-extinguishing system is a manual deluge system, automatic deluge system or pre-action system[17].

16.2.2.3 Fixed fire detection and fire alarm systems - System arrangement

For technical details, this section describes the system arrangement of the different systems described in 9.2.2.1.1.1 as detailed in the standards and regulations.

16.2.2.3.1 Location of detectors

SOLAS II-2/20.4.1 clarifies that the "*spacing and location* [of the detectors] *shall* [… take] *into account the effects of ventilation and other relevant factors*". Further detail is provided in FSS Ch. 9 §2.4.2, together with a table summarizing the maximum spacing between detectors:

"*Detectors shall be located for optimum performance. Positions near beams and ventilation ducts, or other positions where patterns of air flow could adversely affect performance, and positions where impact or physical damage is likely, shall be avoided. Detectors shall be located on the overhead at a minimum distance of 0.5 m away from bulkheads, except in corridors, lockers and stairways.*"

Table 27: Spacing of detectors (FSS Ch. 9 Table 9.1)

Type of detector	Maximum floor area per detector (m^2)	Maximum distance apart between centres (m)	Maximum distance away from bulkheads (m)
Heat	37	9	4.5
Smoke	74	11	5.5

It is to be noted that FSS requirements for detector location are applicable for all kinds of spaces; they are not specific for ro-ro spaces. As a complement, in case the fixed fire extinguishing system is

[16] A decision management system refers to a system able to gather information from several other sub-systems such as ventilation, fire detection, fuel level, fire doors etc. and will support ship management for e.g.:

- Dealing with an emergency by displaying all relevant information on one terminal, helping identifying the emergency scenario and proposing detailed action lists to tackle the emergency
- Training by simulating emergencies
- Maintenance planning

[17] Other fixed fire extinguishing systems are wet pipe systems which include their own thermo-sensitive bulbs and will therefore not rely on a separate fixed fire detection system for activation.

a manual deluge system, automatic deluge system or pre-action system, MSC.1/Circ.1430 makes it clear that:

- only smoke or heat detectors are allowed below hoistable ramps; and
- reduced spacing is to be considered for spot-type heat detectors where beams project more than 100 mm below the deck.

16.2.2.3.2 Section arrangement

On passenger ships, fire detection sections are not allowed to cover more than one Main Vertical Zone (MVZ) (FSS Ch. 9 §2.4.1.4). In addition and on all ships, a fire detection section covering a ro-ro space is to be separated from (FSS Ch. 9 §2.4.1.2):

- Control station
- Service spaces
- Accommodation spaces

For practical purposes, this means that ro-ro spaces are to be provided with dedicated fire detection sections, since ro-ro spaces generally are located in a dedicated Main Horizontal Zone. Only machinery spaces other than category A located in the same horizontal zone could be covered by the same detection section.

In addition, in case the fixed fire extinguishing system is a manual deluge system, automatic deluge system or pre-action system, MSC.1/Circ.1430 requires that fire detection sections be the same as the zones of the fixed fire-extinguishing system: "*The area of coverage of the detection system sections should correspond to the area of coverage of the extinguishing system sections.*"

For practical purposes, on addressable fire detection and fire alarm systems, several sections may be arranged in series on the same electrical cable and separated by suitably located isolators.

16.2.2.3.3 Cable routing

As a general rule, one single fire should not be able to damage a section in more than one location (FSS Ch. 9 §2.4.3.2, requirement for addressable systems) – i.e. the data highway should not pass more than once through a given space as per IACS UI SC117 – and no section should pass twice through a given space. When this cannot be avoided for very large spaces, the maximum possible distance between the two parts of the section is to be ensured (FSS Code Ch. 9 §2.1.6.4, requirement for addressable systems).

Cables are not to pass through spaces with high fire risk such as galleys and machinery spaces of category A, except for serving these spaces and when necessary for power connection (FSS Ch. 9 §2.4.3.1).

In addition, for ships submitted to Safe Return to Port (SRtP) regulations, i.e. ships having a length of 120 m or more or ships having 3 MVZ or more, the fire detection system is to remain operational after a fire or flooding casualty as per SOLAS II-2/21.4. For practical purposes, this generally implies:

- Redundant control panel and input/output cabinets and
- Redundant cable routing or using fire- and flooding-resistant cables[18]

(See SOLAS II-2/21.4 as interpreted by MSC.1/Circ.1369, MSC.1/Circ.1437 as well as NR598)

[18] Fire resistant cables to be tested according to IEC 60331-1 and 2
Flooding resistant cables to be provided with sheathing complying with IEC 60092-359

16.2.2.3.4 Monitoring and control

As a minimum, monitoring and/or control are to be available at the following locations:

- At the safety centre (control panel)
- At the navigation bridge (indicating unit capable of identifying which detector has been activated)

Monitoring and control requirements are summarized in theTable 28, in line with FSS Ch. 9 §2.5.1 and SOLAS II-2/7.9.2 & 7.9.3 requirements.

System operating conditions:

The control panel is to make a clear distinction between:

- Normal condition
- Fire alarm condition
- Acknowledged alarm condition
- Electrical fault condition
- Silenced alarm condition
- The system is to reset automatically to normal operating conditions after all alarms and fault conditions are cleared

Table 28: Monitoring and control requirements

Monitoring and control		**Control panel (Safety centre)**	**Indicating unit (Navigating bridge)**	**Other indicating unit**
Fire detection	Fire alarm (See [9.2.2.2.3])	Visual and audible	Visual and audible	Visual and audible
	Means to acknowledge fire alarm	X (sounders may be manually silenced)		
	Monitoring and Control for: • Fire doors • Ventilation	X		
	Location of sections and spaces covered	X	X	X
Power supplies and electrical circuits necessary for detection system operation	Electrical fault alarm (distinct from fire alarm): • Single open or power break • Single ground fault • Single wire-to-wire fault	Visual and audible		
	Means to acknowledge electrical fault alarm	X		

16.2.2.3.5 Fire detectors

16.2.2.3.5.1 General

The fire detection system is to include fire detectors and manually operated call points.

FSS Code Ch. 9 §2.1.5: All components are to be qualified for operation in marine environment (standard requirements for electrical equipment onboard ships). In addition, fire detectors located in hazardous areas[19] are to be adequate for such use (FSS Ch. 9 §2.3.1.8).

16.2.2.3.5.2 Type of detectors

FSS Code allows “*Detectors […] operated by heat, smoke or other products of combustion, flame, or any combination of these factors.*” (FSS Ch. 9 §2.3.1.1)

As a complement, in case the fixed fire-extinguishing system is a manual deluge system, automatic deluge system or pre-action system, MSC.1/Circ.1430 requires that two types of fire detectors be combined.

In addition, it may be noted that several Flag States and classification societies require smoke detectors exclusively or in combination with other detectors in ro-ro spaces. BV Rules require that smoke detectors are installed in ro-ro spaces (NR467 Pt C, Ch. 4, Sec. 12 [3.1.1]). Similar requirements are

[19] For practical purposes, fire detectors installed in ro-ro spaces below the bulkhead deck are in Zone 1, others are in Zone 2, since fire detectors are fitted on the deckheads.

given by the US Coast Guard and the Swedish Flag. The MCA (UK Flag Administration) requires smoke detectors exclusively or a combination of smoke and flame detectors.

MSC.1/Circ.1615 proposes:

> "2.3 Fire detection in open ro-ro spaces
>
> In open ro-ro spaces on all ro-ro passenger ships, if smoke detectors are installed they should be supplemented with other effective means of detection e.g. flame detectors, heat detectors."

The requirement to have at least smoke detection in ro-ro spaces is based on the fact that smoke detection is considered as more reliable than standard flame or heat detectors. Standard heat or flame detectors are also considered less efficient in ro-ro spaces since:

- Heat sensors located on garage space deckhead were expected to result into quite long activation times due to deck height
- Flame detectors were expected to lead to a number of false alarms due to reflections etc.

16.2.2.3.5.3 Qualification and performance standards

In general, fire detectors are to be qualified according to EN 54:2001 and IEC 60092:504 (FSS Ch. 9 §2.3.1 and MSC/Circ.1035). Usual performance requirements are:

- For smoke detectors: Activation for 2% obscuration/m ≤ smoke density ≤ 12.5% obscuration/m

  "Smoke detectors […] shall be certified to operate before the smoke density exceeds 12.5% obscuration per metre, but not until the smoke density exceeds 2% obscuration per metre"

- Heat detectors: Activation when 54°C ≤ temperature ≤ 78°C (temperature increase rate ≤ 1°C/min)

  "Heat detectors shall be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C"

- Carbon monoxide detectors: Alarm threshold set at 40ppm, sensitivity settings to be adjusted considering the fire hazard, likely source and risk of false alarm.

In addition, provisions are given for in-service function testing (FSS Ch. 9 §2.3.1.6).

16.2.2.3.6 Electrical arrangement

16.2.2.3.6.1 System architecture

The system is to be organized into sections as per FSS Code Ch. 9 §2.1.4 and 2.4.1.1.

The first initiated fire alarm is not to prevent any other detector from initiating further fire alarms as per FSS Code Ch. 9 §2.1.6.3, applicable to addressable systems.

16.2.2.3.6.2 Components

- The control panel is to be tested according to standards EN 54-2:1997, EN 54-4:1997 and IEC 60092-504:2001 (FSS Ch. 9 §2.3.2)
- Cables are to be flame retardant as per IEC 60332-1 (FSS Ch. 9 §2.3.3)
- Cables routed through MVZ that they do not serve and cables to control panels in an unattended fire control station are to be fire resisting as per IEC 60331 (FSS Ch. 9 §2.3.3)

16.2.2.3.6.3 Sources of power

16.2.2.3.6.3.1 Continuous fire detection capability

The fixed fire detection and fire alarm system is to be fed from two sources of power with separate feeders, including an emergency source of power (FSS Code Ch. 9 §2.2.1). An emergency source of power has to comply with the requirements of SOLAS II-1/42 and 42-1 regarding location and autonomy. Especially, it has to be able to supply the fire detection system for 36 hours, after which it has to be capable of operating the fire alarm for 30min (FSS Ch. 9 §2.2.4). It is either the ship emergency generator (+ transitional source of emergency power) or dedicated accumulator batteries (FSS Ch. 9 §2.2.4 & 2.2.5).

An automatic change-over switch is to be provided to manage the transition between the main and emergency source of power, and a fault should not lead to the loss of both power supplies.

No temporary loss of the fire detection capability due to this change-over switch is accepted. In addition, a transitional battery may be required if the temporary loss of power can damage the fire detection system as per FSS Ch. 9. §2.2.2.

Although the alarm sounder is not formally required to be part of the fire detection system, IACS UI SC35 makes it clear that it is to be powered from a main and emergency source of power and from the transitional source of emergency power where required.

16.2.2.3.6.3.2 Sizing of the source of power

The power supply is to be sufficient for operation with 100 detectors activated, or all detectors provided onboard if this number is lower than 100 (FSS Ch. 9 §2.2.3).

16.2.2.3.6.4 Consequences of a fault

After an electrical fault or electrical failure:

- Identification capability is to be kept in the whole section, except for the faulty detector (FSS Code Ch. 9 §2.1.6.1, applicable to addressable systems)
- The initial configuration is to be restored (FSS Code Ch. 9 §2.1.6.2, applicable to addressable systems)

16.2.2.3.6.5 Temporary disconnection

FSS Code Ch. 9 §2.1.1 allows temporary disconnection of the fire detectors in ro-ro spaces during loading and off-loading, provided:

- Detectors in other spaces remain operational
- Fire patrol is maintained in the ro-ro space while the detectors are disconnected
- The detectors are automatically re-connected after a pre-set duration

MCA (UK Flag Administration) clarify in their guidance that:

- Manual call points and manual release mechanisms may not be disconnected
- The duration of the timer is to be adapted to the time of loading/unloading
- The central unit is to indicate whether the detector sections are disconnected or not

16.2.2.4 Sample extraction smoke detection systems - Performance

16.2.2.4.1 General

The system is to be capable either of continuous operation or of scanning at regular intervals (with a maximum scanning interval defined in FSS Code 10.2.1.2)

[FSS Code 10.2.1.2]

After installation, the system is to be subjected to a functioning test performed using smoke generator machines. For ro-ro and vehicle spaces, the alarm is to be activated within 180s after smoke is introduced at the smoke accumulator furthest from the control panel.

[FSS Code 10.2.4.2.2

16.2.2.4.2 Performance standard

The sensing unit shall be certified to operate before the smoke density within the sensing chamber exceeds 6.65% obscuration per metre.

[FSS Code 10.2.2.1]

16.2.2.4.3 Alarm

A visual and audible alarm is to be activated on the bridge and at the control panel (see §16.2.2.5.1) in case of smoke detection. The alarm on the bridge is not required to provide any indication on the location where smoke has been detected. It is expected that the crew can then determine at the smoke sensing unit which cargo hold is on fire and operate the pertinent three-way valve for discharge of the extinguishing agent.

[FSS Code 10.2.1.1.4, 10.2.4.1.1]

16.2.2.5 Sample extraction smoke detection systems - System arrangement

16.2.2.5.1 General arrangement

The system consists of:

- Sampling pipes with smoke accumulators at their open ends
- A control panel which includes a viewing chamber or smoke sensing units, capable of detecting smoke if collected in the smoke accumulators.

The system may be combined with a gas fire-extinguishing system, i.e. the sampling pipes may also be used to convey the fire-extinguishing gas to the ro-ro cargo space. In this case, 3-way valves are required in order to properly segregate the smoke analysing function from the gas fixed fire-extinguishing system.

[FSS Code 10.2.1.1]

16.2.2.5.2 Space identification

Attention is paid to proper identification of the spaces where smoke may be detected. This first works through the arrangement of sampling pipes and associated smoke accumulators : smoke accumulators from more than one enclosed space are not to be connected to a given sampling pipe and, more generally, the sampling pipe arrangement is to ensure that the location where smoke is present can be readily identified.

[FSS Code 10.2.3.1.5, 10.2.3.2.1]

In addition, maps or equivalent information is to be displayed close to the control panel or repeater units in order to allow proper identification of the space where smoke has been detected.

[FSS Code 10.2.4.1.3]

16.2.2.5.3 Sampling pipe routing

Considering that the sampling pipes serve an hazardous area, i.e. a space where explosive gases may be present, general requirements are included with a view to avoid the leakage of any toxic or flammable substances or fire-extinguishing media into other spaces onboard.

[FSS Code 10.2.1.3]

Several smoke accumulators may be connected to a given sampling pipe, however:

- All those smoke accumulators are to be located in the same enclosed space, with a view to ensure easy identification of the space on fire
- The sampling pipes need to be properly balanced, so as to ensure that equal quantities of airflow are extracted from each interconnected accumulator

[FSS Code 10.2.2.4, 10.2.3.1.4, 10.2.3.1.5, 10.2.3.2.1]

16.2.2.5.4 Detector location

The FSS Code requires at least one smoke accumulator per enclosed space, also adding a number of requirements aimed at ensuring an efficient positioning of those accumulators, taking into account shielding effects and the ventilation in the spaces covered.

[FSS Code 10.2.3]

Additional smoke accumulators are required in the upper part of exhaust ducts and in the upper and lower part of spaces with movable tweendecks.

[FSS Code 10.2.3.1.2, 10.2.3.1.6]

16.2.2.5.5 Components

General requirements are provided in order to ensure that all components of the system are suitable for marine use. In addition, a number of requirements are provided in order to ensure the reliability of the smoke detecting unit, referring to standards EN 54-2 (1997), EN 54-4 (1997) and IEC 60092-504 (2001). FSS Code also introduces specific redundancy requirements, e.g. for the smoke extraction fans.

[FSS Code 10.2.1.4, 10.2.1.5, 10.2.2]

16.2.2.5.6 Electrical arrangement

16.2.2.5.6.1 Power supply

Any loss of power for the system is to initiate a dedicated visual and audible alarm at the navigation bridge and an alternative power supply is required for the system.

[FSS Code 10.2.1.6, 10.2.4.1.4]

16.2.2.5.6.2 Alarm or fault conditions

In case of smoke detection alarm or fault conditions:

- Clear distinction is required between normal, alarm, fault and silenced conditions
- It is to be possible to acknowledge the signals from the control signals from the control panels and it is allowed to silence the audible alarms
- The system is to reset automatically to normal operating conditions after alarm and fault conditions are cleared

[FSS Code 10.2.4.1.5, 10.2.4.1.6]

16.3 Operational and production aspects

This section aims to discuss means of current fire detections to identify what core functions future fire detection systems should inhabit and what considerations must be taken into account.

When considering requirements for new means of fire detection, it is important to note, that the following is practical considerations regarding the subject, however new means may very well be beyond the scope of requirements considered here, since the considerations are based on what exists, and the current mindset, not what could be developed in terms of equipment and new insights.

Discussing requirements of fire detections, a questionnaire filled out by the crew on board a number of DFDS vessels is providing additional background information about the topic.

Going forward first known problems will be discussed, then current means of detection followed by suggestions of improvement seen from DFDS' perspective.

A new aspect is the early detection of electric car Li-ion battery fires. Considering that in case of a thermal runaway the gas emission comes before heat and that detection equipment therefore is needed to be very close to the source, this complicates means of detection considerably.

16.3.1 General fire detection on board

General fire detection means on board, is described below. Please note that this is a general description, and actual means may vary from ship to ship, both as a matter of how the ship is operated and from special requirements on the vessel. Also note that if the crew find that additional measures are needed (e.g. when doing hot works on board) they may dispatch a fire watch or whatever else they deem necessary given what they have to work with on board.

Detection methods vary depending on what area is regarded on board. On DFDS vessels, the means of fire detection is guided by a combination of SOLAS and the national Danish authority requirements. Combined these regulations are what the design companies uses when fitting the ship with fire detectors.

The fire detection system consists of two main parts; all the different detectors, and the IAMCS system. IAMCS connects all detectors with the general alarm and the fire panels showing where on the ship the cause of the alarm is located. The IAMCS is placed and operated on the bridge but might have slave panels in fire stations and engine control room.

In general, going forward it is required for DFDS vessels to be equipped with an addressable fire detection system covering alleyways, control stations, service spaces, all type of cargo decks except open weather deck, engine rooms and machinery spaces etc.

Systems include a computerized central unit with graphic display.

The fire detection system must also be the indication and control system for fire doors and fire dampers, if any, and shall have built-in monitoring circuits that are intended to monitor that the equipment is in satisfactory order at all times and indicates faults that could prevent a fire alarm.

If a true alarm condition is activated by detectors the alarm will sound. A time delay of up to two minutes is normal (for detectors only), however a pre-warning is given on the bridge. Subsequently the general alarm will then be activated.

If a push button is manually activated, it will automatically and immediately activate alarms - no time delay is permitted here.

Timers for temporally disconnecting fire detectors in cargo decks are installed in the CCR. It should be possible to disconnect each deck for up to six hours, to make repairs.

Timer switches for loop-disconnection are fitted in the engine room workshop (not linked to manual push buttons).

The power supply is 230V AC, from the emergency switchboard and in-built 24 VDC batteries with charger.

All fire detectors are located so that they are easily accessible for testing.

A sufficient number of optical and ionizing smoke detectors, temperature detectors of type Rate of Rise and IR flame detectors are installed as seen fit and in any case according to the Class and IMO/SOLAS rules.

For ro-ro areas a combination of smoke and heat detectors are installed.

Accommodation ventilation fan stops automatically when the fire alarms go off and by emergency stop push button on bridge.

Manually operated alarm pushbuttons are installed throughout the Vessel according to rules. General alarm will be installed according to the rules, covering the whole ship.

Fire patrol is only mandatory on passenger vessels. (See IR05.06)

16.3.2 Concerns what is done beyond the SOLAS regulations

DFDS is as a minimum following the SOLAS and national regulations. What is done beyond those regulations is listed below. However due to the nature of the design process no record is kept of what is up to regulation standards and where company demands exceeds the regulations, meaning that this list is not complete.

- Water monitors on weather decks.
- Extra firemen’s outfit at firemen stations.
- Soft mimic screen on bridge indicating area for activated fire detector.

Furthermore, a company rule of only charging li-ion batteries when someone is present – also for cell-phones in crew cabins – is implemented, to prevent self-ignition.

16.3.3 Detection of fire focussing on main fire hazards on board open and closed ro-ro spaces

A general monitoring of fire hazards is essential to safety on board, however special points of focus on known fire hazards are also considered.

Existing fire hazards on board are known to be:

1) Faulty reefer units
2) IMDG cargo
3) Leaking IMDG cl. 3 on Weather deck and Upper deck (e.g. gasoil)
4) Flammable materials such as paint or oil
5) Fires originating from hot work of all kind and short circuits
6) Car carriers (for road transport) loaded with old cars
7) Trucks with additional equipment connected in the driver’s cabin (such as heaters, kettles or navigational equipment)
8) Electric cars with Li-ion batteries, thermal runway of ignition by external factor

Please note the numbering is not symbolizing a risk assessment, or what is more likely to occur.

Detection of faulty reefer units are currently being dealt with by a quick visual inspection during loading of cargo, when the crew on board also connects the reefer unit. The visual inspection is based on experience, and new crewmembers get instructions by colleagues if needed. However, no official job training is in place for this job, as it is up to the crew on board how they manage this. The ro-ro vessels do not have a designated fire patrol when sailing or in port, unless this is for some reason deemed necessary by the crew on board. The reefer units are non the less checked every 4th hour to register the temperature. In order to avoid short circuit of reefers maintenance of reefer cables and plugs on board the vessel is important. If the mate or deckhand on board finds that the cables are not up to standards, they are sent ashore for repair or to be discarded by a shore-based unit. The plug on the reefer itself, however, is controlled and maintained by the reefer unit's owner. Improvements of cable storage could help extending lifetime of cables, as the current storage does not protect them from water or dirt.

When carrying cars, DFDS has a company standard of batteries of cars on board them must be disconnected before loading. This applies only for cars transported B2B, not for private cars.

Regarding equipment in truck driver's cabins, the drivers are instructed that it is not allowed to operate and utilize such equipment during the voyage. This instruction is however not always followed, and besides being told off by the crew it has no consequences to the drivers.

To minimize the fire hazard of IMDG cargo, the unit, corresponding paperwork, and any special transportation requirements are checked upon loading, and proper segregation is ensured. Beside this, no special monitoring is provided for IMDG cargo.

Flammable materials including paint, oils etc. are typically concentrated in paint lockers, engine room workshop areas and in the galley. These places typically have separate fixed firefighting CO2 systems. Paint is in addition stored in assigned lockers.

16.3.4 Operational problems

Many trailers have good waterproof covers for the cargo, which during a fire contains smoke for a period and makes the sprinkler system inefficient for direct extinguishing of the fire until the fire has spread enough to pierce through the top coverage.

Not all vessels have means of fire detection on the weather deck. Specially the aft weather deck is payed little attention, as it, unlike the foredeck, does not have the officers of the watch looking out over the deck as a natural part of their job.

Some ships have false alarms from too much humidity in the cargo space when loading when it is raining or snowing.

16.4 Environmental aspects

That the on-board work environment is damaged if a fire should occur is almost inevitable, but damages to ship, crew and cargo should be minimized as much as possible. For the detection system this means that time is essential, and that the quicker the system can respond to a fire the less chance of harm is to be expected.

With regards to the general environment, it is of course expected that a fire detection system is made of materials that does not worsen the situation of a developing fire if catching fire themselves.

It is also expected that the fire detection equipment is made of a good enough quality ensuring a long life for the system minimizing the lifelong cost and taking life cycle assessments into account.

Also, materials with the least environmental footprint should be preferred.

16.5 Proposal for development and restrictions

For designing a future fire detection system, the following is to be considered:

A system should have no false alarms but still detect fire while the fire is in such an initial state that it can still easily be extinguished.

The system should be as simple as possible, both to setup, to maintain and to use.

A good fire detection system must be approved by SOLAS and classification societies.

A good fire detection system does not interfere with the cargo space and takes up a minimum amount of space.

A good fire detection system must be easy to install on board and should be able to integrate all means of fire detection on board, so that one - and only one system is covering all fire detection as well as remotely released fire extinguishing remedies.

If a new fire detection system is to be implemented on board it should thus either completely substitute the existing system, so that this can be un-installed, or be able to integrate with the existing system.

For setting up equipment on board, it should be considered that pulling cables are extensive work and expensive, as metalwork is to be expected, and that cables going through watertight departments complicates setup.

With regards to maintenance - the less manual inspections and care is needed the better. Point is, when every smoke detector on board is to be tested it takes 2 persons around 2-4 weeks to locate and test all detectors depending on the vessel, but vessels being large ro-ro or ro-pax around 180m length. Thus, a self-testing system would save many man-hours of tedious work and make sure that no detector is forgotten or not noticed. Such a system could thus notify the crew in case of errors or sabotage.

The perfect fire detection system is maintenance free.

With regards to alarms, it is important that a fire detection system sends a clear signal to the bridge on where the source of the fire is located. It is also important that if a fire starts and begins to spread the system does not keep sending alarm messages that disturbs the already stressful work on the bridge of taking control of the situation. Instead the system should support the officers to make informed choices and to keep an overview of the situation. This does *not* mean that the system should stop giving feedback on the development of the fire, just that it could be done in a better way that what is the current procedure.

Spare parts should be easy and cheap to attain, and repairs should be easy to make.

A fire detection system should be able to run without downtime or have a back-up solution if downtime should occur.

A new fire detection system should take less of the crew’s time than the systems in place today.

A new system that could enable inspection of cargo holds to be done from the bridge in a thorough manner without adding to the number of sensors and cameras installed could add value and safety on board.

Digital manuals for all equipment and systems, so that it is easy to search for specifics of the equipment or system, would reduce time used to gather necessary information in a critical situation.

The fire detection system should never rely on any kind of shore connection or internet access. It should always be fully functional when using on-board systems.

Decision support from AI. An interesting improvement to look further into, would be to train an AI system to sort out which detectors are active, show it on a 3D map, and come up with an attack plan, including where cooling should be applied and what means of fire extinguishing should be used depending on what type of cargo have caught fire.

Maybe even autonomous firefighting could be interesting to look at for the purpose of reducing the number of crew who are exposed to contact with the fire. Such a device would also not have the same restrictions towards heat, smoke and safety as a crewmember have.

A system that covers the weather deck should not only be weather resistant, but also not have an increasing amount of false alarm when exposed to saltwater spray, dirt or other and should be able to function with a minimum of cleaning sensor parts.

For detection of thermal runaway situation, an idea is to investigate an efficient way to detect the first gases emitted (CO) and what time delay the normal roof mounted smoke detection systems have. Impact of ventilation need be considered.

Heat detection should not be ruled out, even if a heat rise comes after gas. Likely it is needed to look onto other locations or systems closer to the source. Temporary detection stickers may be considered such as example illustrated on Figure 29.

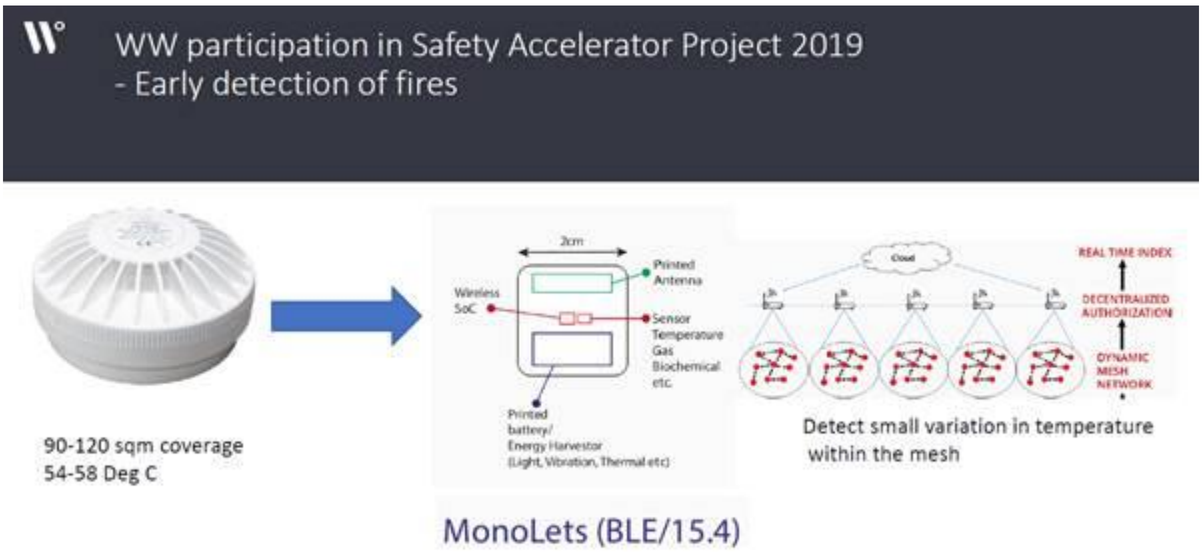


Figure 29. Early detection of fires - example

16.6 Conclusion

The perfect fire detection system does not exist, but there are some functions that could have other shapes and ways to operate than how current systems does, including new technologies. However, simplicity, reliability and costs are important factors for a new fire detection system to pay attention to as well, if it is to be useful to the maritime industry. Also, weather decks are in general neglected when it comes to fire detection, this might turn out to be worst for the aft decks.

To look further into where official regulations begin and where company demands starts is of further interest, however not so easily acquired as company specifications for vessels do not distinguish between the two.

To keep the fire detection systems up to date, is of big importance, since new technologies and materials enter the cargo space, and thus changes the requirements of fire detection on board the world fleet.

17 Means for automatic fire confirmation, localization and assessment - Action 9-C

Main author of the chapter: Sif Lundsvig, DFDS

This chapter aims to discuss automatic fire confirmation, localization, and assessment to identify what core functions should be considered in fire detection systems aiming to enable these three parameters. Further, applicable regulations are described.

Additional related information about muster plans, division of tasks and responsibilities can be found in Chapters 6, 10, 11 and 15.

17.1 Short description of the addressed Action

The objective of Action 9-C is to investigate and develop new and advancing technologies for automatic visual fire confirmation and localization, through the following:

- Definition of conditions and technologies for visual fire confirmation and localization
- Investigation and development of technologies for visual fire confirmation and localization

17.2 Regulation and requirements review

Main author of the chapter: Blandine Vicard, BV

17.2.1 General

17.2.1.1 Scope

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 9-C i.e. "technologies for visual fire confirmation and localization".

17.2.1.2 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable to old ships.

Table 29: List of documents used for the review of regulations for Action 9-C

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
	DNVGL Rules for the Classification of Ships, July 2019
	LR Rules and Regulations for the Classification of Ships, July 2016
Flag Administration Rules	MMF (French Flag Administration) Division 221 "Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage", 28/12/17 edition
	US Coast Guard Code of Federal Regulations (CFR) 46, 2019 online edition
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

17.2.1.3 Onboard procedures

It is to be noted that IMO requirements regarding onboard procedures and actions to adopt in case of fire emergency remain on the general, functional requirement level. The detail of the actions to be actually taken is reckoned to be case-specific and ship-specific, and is therefore left to specific onboard procedures, safety management system, and crew members experience and analysis of the situation. It is generally required that the crew members know the systems, how to use them and how to maintain them:

- SOLAS II-2/15 [5] provides very high-level requirements about the onboard instructions, organisation and training, as well as about the necessary knowledge and skills of crew members.

IMO ISM Code [38] requires that "every Company should develop, implement and maintain a Safety Management System (SMS) which includes […] instructions and procedures to ensure safe operation of ships and protection of the environment in compliance with relevant international and flag State legislation." The ISM Code contains one chapter about '7 Shipboard operations' and another about '8 Emergency preparedness' with high-level requirements in this respect.

17.2.2 Requirements

SOLAS requirements [5] regarding means for automatic fire confirmation, localization and assessment in vehicles and ro-ro spaces are very limited. Basically, a fixed fire alarm and fire detection system is to be provided in vehicle and ro-ro spaces, allowing to identify at least the space on fire and possibly the area in the concerned space – see more details on the fixed fire alarm and fire detection system in Chapter 16 for closed and open ro-ro spaces and Chapter 15 for weather decks.

[SOLAS II-2/20.4]

Then the basic assumption is that fire confirmation will be ensured through crew inspection.

It has been noted however in recent regulatory discussions that video cameras are usually provided in ro-ro and vehicle spaces of ro-ro passenger ships in pursuance of SOLAS regulation II-1/17-1.3 [5], which requires "Television surveillance and a water leakage detection […] to provide an indication […] of any leakage through inner and outer bow doors, stern doors or any other shell doors which could lead to flooding of special category spaces or ro-ro spaces", and that such cameras could be used for the purpose of fire confirmation, although they are not currently required to cover the whole ro-ro or vehicle space. Accordingly, IMO interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships MSC.1/Circ.1615 [11] recommends to install television surveillance systems in ro-ro and vehicle spaces of ro-ro passenger ships for fire confirmation purposes.

[MSC.1/Circ.1615 §2.2]

17.3 Operational aspects

When an indication of a fire on board is given, either by alarms or other suspicions, it needs to be confirmed, localized and assessed.

17.3.1 Localization

Fire can be indicated either on alarm panels on the bridge or other place on board where alarm panels are located. If the fire is not indicated by an alarm, it might be discovered by CCTV or by crew on board. Both these situations provide a visual localization to the person who first detects the fire. A member of the crew might also discover a fire by smoke or smell, but in most cases this will provide a visual localization as well.

17.3.2 Confirmation

Is done manually in almost all cases. If the fire is discovered by a member of the crew directly, it is done simultaneously as localization and assessment. If discovered via alarms or CCTV, a crewmember is dispatched for confirmation.

17.3.3 Assessment

First assessment is done by the first crewmember on scene, the severity of the fire is evaluated and reported back to the officer of the watch. If the fire is small enough it is sought extinguishing immediately on scene. Otherwise, the crew member must retreat, and other means of firefighting will be applied.

17.3.4 Repeat

The three basic tasks; localization, confirmation and assessment are not something one can "tick off" when first done. When a fire is on board, the process is continued as the situation develops, often rapidly. The first round is critical due to the fact of time being a success factor, the next repetitions due to better overview and decision making. In any of the localization, confirmation and assessment rounds done on board, it is of the very essence that information gathered is trustworthy.

17.3.5 Trust

Manual localization, confirmation and assessment is prioritized, either as a first response, where a crewmember just verifies the scene of action, or later as firefighters can report back the development of the situation. Other means of verification of the basic tasks (localization, confirmation and assessment) may be just as useful, but only if they can provide a sufficient level of trust for the crew, e.g. CCTV cameras provide a high degree of trust, as it creates a similar experience as the visual inspection, yet distrust coming from lack of using other senses and the eventual blind spots of the camera. Detectors only creating an alarm has a higher level of distrust, as in that case the crew must rely solely on the system. The frequency of the false alarms in the detection system has a significant influence in the crew's reliance. Some systems mitigate this by indicating what the sensors are actually responding to. An example is a smoke detector giving an alarm, but the system indicating that the sensor is reacting to a high degree of moist in the air, combined with the officer's knowledge that this alarm is situated in a passenger cabin and that it is morning, when people often take showers, can create an impression where the system provides useful information instead of false alarms, which certainly increases the reliance in such system.

17.4 Proposal for development and restrictions

In order that localization, confirmation and assessment can be successfully automated, the procedures replacing them needs to take into account how many human senses must be mimicked to increase the crew's trust. Verification methods are equally important, and other information surrounding a scene of action may prove crucial as well.

The crew should be able to get all the information that a manual assessment would have provided and if not, it needs to be considered what information cannot be gathered from automatic procedures and in what way this lack of information can steer the decision process regarding fire control actions.

As a positive side, automatic localization, confirmation and assessment can provide access to fire scenes that are unsafe or not accessible for the crew, as well as the safety of the person in charge does not need to be considered, e.g. a drone could access a space flooded with inert gasses, bringing valuable information on effectiveness of the fire extinguishing measure.

Automatic localization, confirmation and assessment of a fire also opens up for logging and relaying information both onboard the ship and onshore, thereby replacing the crew from task of communication with shore staff or authorities. Removing tasks from time-pressed personnel in a stressed situation is a big advantage, however it needs to be done in a way that creates trust and safety, releasing the potential misunderstandings that needed to be sorted out.

As a general comment on automation of basic fire tasks, initially both manual and automatic procedures have to take place in parallel, covering and substituting each other. Automated solution should not fully supplement manual one in the beginning as there is also a learning curve when new technologies are brought on board.

17.4.1 Supplementing the limitations of manual observation with automatic systems

The manual on-site evaluation of a fire incident, which is based on human senses and the operator's ability to assess and combine information, can give a very detailed picture of the situation that is very difficult to replace with fully automated system. However, the manual observations have some limitations that an automatic system can supplement.

Time: The operator will not be able to make observations until it is on very site and this may come with a time delay. Contrariwise, automatic systems are always on site and can provide information on what has happened even before the very incident is initiated.

Sensors: The human senses can detect and process a large number of parameters and distinguish between the smell of many different gases in the air. Electronic sensors can, on the other hand, measure exact concentrations of gases like carbon monoxide that the human cannot sense. Infrared detectors can see the temperature on surfaces at a long distance that the human senses cannot. Electronic sensors may also be located on many different locations giving a spatial distribution of the parameters they can detect.

Hazardous environment: The operators cannot safely enter an area where the environmental conditions like gas concentrations in the air or temperatures are unsafe, without proper firefighting equipment. Electronic systems may operate in most types of gases and in a wider range of temperatures.

The devil is in the details: Humans have the ability to combine the situation with practical experience on the spot, and relay information that automated sensors cannot, e.g. is there a room for a firefighting team to manoeuvre from a certain angle? Where is the closest hose connection? Are there elements of the surrounding cargo that should be considered, such as material, size, fire resistance? Is there a problem with cargo not being lashed sufficiently in extreme weather situations? The ability of the human brain to collect and process certain information from the environment and to draw conclusions based on acquired experience is still almost impossible to fully automate.

17.5 Conclusion

The perfect fire detection system still does not exist, and there are certain functions that could have different features and modes of operation in comparison with current systems, including new technologies. Moreover, simplicity, reliability and costs are important factors for a new fire detection system to pay attention to as well, in order to be applicable to the maritime industry. Also, weather decks are generally disregarded when it comes to fire detection, especially for the aft area, and this issue should be further investigated.

18 Local application fire-extinguishing systems - Action 10-A

Main author of the chapter: Urban Lishajko WAL

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 10-A i.e. Local application fire-extinguishing systems.

18.1 Short Description of the addressed Action

The intent of the Action 10-A is to develop and demonstrate a low-cost, low-weight and high-efficient (automatic) system which can be released locally and rapidly at early stages of a fire. The performance objectives are to prevent fire spread from a vehicle under fire to adjacent vehicles, to prevent the fire from spreading to other vehicle spaces and to limit structural damage. Further, the system could allow more time for manual firefighting and to limit the size of the fire prior the activation of the CO2-system. The following tasks will be conducted under the action:

- Definition of conditions for use of local application fire-extinguishing systems
- Development of fixed local application fire-extinguishing systems by system suppliers
- Large-scale fire performance validation of selected local application fire-extinguishment solutions

18.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

18.2.1 General

18.2.1.1 Scope

This section aims at giving an overview of the requirements applicable to ro-ro spaces regarding Action 10-A.

The wording “local application”, when discussing ship fire safety, is usually associated with the Fixed Water-Based Local Application Fire Fighting Systems (FWBLAFFS) that have been required by SOLAS in machinery spaces since 01/07/2014. Those systems consist of a limited number of water spraying nozzles installed above a specific equipment which is associated with a high fire risk. The nozzles are coupled with fire detection and can be activated automatically upon fire detection, because their activation entails no significant risk for the ship or crew. It is to be noted, however, that the current regulations do not require any similar “local application fire-extinguishing system” in ro-ro spaces.

As a consequence, the present document will focus on fire-extinguishing systems in ro-ro spaces that could be activated with view to cover only specific parts of the ro-ro space and without prior evacuation of the space.

18.2.1.2 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

A brief summary of the main regulation changes related to Local application fire extinguishment is provided in Table 30 with a particular focus on regulations relevant to Action 1-A.

Table 30. Summary of regulation changes

Regulation change	Application date	Adoption date	Summary
SOLAS 74	1980	1974	Introduces the principle of horizontal fire zone for ro-ro spaces / special category spaces with: • Structural fire protection • Fixed fire extinguishing system ("drencher" type) • Fixed fire detection system
A.123(V)	25/10/1967	25/10/1967	Recommendation on fixed fire extinguishing systems for special category spaces Covers "drencher" type systems installed as per SOLAS II-2/20.6.1.1.3
MSC.1/Circ.914	04/06/1999	-	Guidelines for the approval of alternative fixed water-based fire-fighting systems for special category spaces Allows water-mist fixed fire-extinguishing systems
MSC.1/Circ.1272	09/05/2008	-	Guidelines for the approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces equivalent to that referred to in resolution A.123(V) Supersedes MSC.1/Circ.914
MSC.1/Circ.1430	21/05/2012	-	Revised Guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces Supersedes both MSC.1/Circ.1272 and IMO resolution A.123(V)
MSC.1/Circ.1430/Rev.1	01/01/2021	-	Clarification of control requirements for deluge systems

The review is mainly based on the documents listed in Table 31.

Table 31. List of documents used for the review of regulations for [Objet]

IMO Documents	SOLAS Convention, as amended
	FSS Code, as amended
	MSC.1/Circ.1430, as revised and amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
	DNV-GL Rules for the Classification of Ships, January 2017
	LR Rules and Regulations for the Classification of Ships, July 2016
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 28/12/17 edition
	US Coast Guard Code of Federal Regulations (CFR) 46, 2019 online edition
	Swedish Transport Agency “Comments and interpretations by the Swedish Transport Agency regarding IMO Conventions”, version 03 dd.15/05/2017
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

18.2.2 Requirements

18.2.2.1 General

SOLAS II-2/20.6.1 requires a fixed fire-extinguishing system to be provided in every vehicle or ro-ro space. It is to be noted that this requirement does not apply to weather decks intended for the carriage of vehicles, because weather decks are not “spaces”.

Pure cargo vehicle or ro-ro spaces capable of being sealed from outside may be provided with:

- Fixed gas fire-extinguishing system – typically CO_2; or
- Fixed high expansion foam fire-extinguishing system; or
- Fixed water-based fire-extinguishing system – “drencher” type or equivalent.

In the case of special category spaces – i.e. passengers can have access to the garage – or if the space cannot be sealed, only the fixed water based fire-extinguishing system is allowed.

[SOLAS II-2/20.6.1.1 and II-2/20.6.1.2]

The above systems are intended for the protection of the ro-ro or vehicle space as a whole. Especially, it is to be noted that fixed gas fire-extinguishing systems work by inerting a sealed volume, and, as a consequence, cannot be released on a smaller part of the ro-ro or vehicle space only. High expansion foam fire-extinguishing systems may be separated into sections and could theoretically be released on one section only. However, it is understood that full evacuation of the space would still be needed prior to release of the system.

[For high expansion foam systems, see FSS Code Ch 6]

Consequently, high expansion foam and gas fire-extinguishing systems will not be further detailed and this report will focus on fixed water-based fire-extinguishing systems, i.e. ”drencher”-type systems and equivalent high pressure water-mist systems. All kinds of water-based fixed-fire extinguishing systems that may currently be installed in ro-ro or vehicle spaces fall under the scope of IMO MSC.1/Circ.1430/Rev.1.

18.2.2.2 Performance

The fixed water-based fire-extinguishing systems may be either:

- Prescriptive-based systems, i.e. systems dimensioned to provide a specified minimum water discharge density, which is specified in IMO MSC.1/Circ.1430/Rev.1 depending on the type of system and on the deck height. The required water flow varies between 5 and 20 L/min/m²; or
- Performance-based systems, i.e. systems that have been fire tested in standard fire scenarios as defined in the appendix of MSC.1/Circ.1430/Rev.1. In this case the available water flow is to be consistent with the tested arrangement.

18.2.2.3 System arrangement & sectioning

MSC.1/Circ.1430/Rev.1 provides detailed requirements addressing the following concerns:

- Sectioning: The system has to be divided into sections, each section being isolated and controlled through a control valve;

[MSC.1/Circ.1430/Rev.1 §3.2]

- Proper dimensioning of the pumps and piping. MSC.1/Circ.1430/Rev.1 includes precise specification of the areas that need to be covered simultaneously, thus effectively dimensioning the required pumps;

[MSC.1/Circ.1430/Rev.1 §3.3, 3.7, 3.22, 3.23, 4.1 & 4.2 or 5.1, 5.4 & 5.5]

- Redundancy and reliability of the pumps. In addition a connection to a seawater inlet is required as a backup allowing for indefinite operation of the system;

[MSC.1/Circ.1430/Rev.1 §3.4 & 3.8 & 3.9]

- Proper design and qualification of the nozzle components;

[MSC.1/Circ.1430/Rev.1 §3.10 & 3.11, 4.3 & 4.4 or 5.3]

- Positioning and arrangement of the nozzles;

[MSC.1/Circ.1430/Rev.1 §4.5 & 4.6 or 5.2]

- Testing, user-friendly operation and maintenance of the system.

[MSC.1/Circ.1430/Rev.1 §3.12 to 3.18, 3.20, 3.21]

18.2.2.4 Controls

The system may be activated either manually, or automatically, or both. Automatic activation is normally coupled with the fixed fire detection and fire alarm system specified by the FSS Code.

[MSC.1/Circ.1430/Rev.1 §3.1]

In any case however, care is taken to preserve an option to manually open the section control valves: they have to be located out of the protected space, easily accessible and properly marked.

[MSC.1/Circ.1430/Rev.1 §3.2 & 3.2.1]

In addition, provisions are made to ensure centralised control and monitoring for deluge systems, both in the valve room and at the continuously manned control station. Especially, it is to be noted that the specific section which is activated has to be identified in the central control station.

[MSC.1/Circ.1430/Rev.1 §3.2.2 & 5]

18.2.3 Other regulations

It is to be noted that IMO instruments include detailed specifications for a large number of fixed fire-extinguishing systems, a number of which are water-based fixed fire-extinguishing systems. Among those, FWBLAFFS have been required in category A machinery spaces since 01/07/2014.

Those systems are required by SOLAS II-2/10.5.6 and specified in detail in MSC.1/Circ.913, as amended by MSC.1/Circ.1276.

The principle of these FWBLAFFS is that sets of water-mist nozzles are installed above hot spots or identified equipment. Those nozzles are activated automatically upon fire detection (positive detection by at least two sensors) and may also be activated manually through push buttons provided in the space. Precautions are taken so that the activation of the nozzles remain compatible with the equipment still running (e.g. electrical equipment protection).

[SOLAS II-2/10.5.6, MSC.1/Circ.913 as amended, IACS UR E20]

18.3 Operational aspects

18.3.1 Fire assessment and manual fire fighting

The cargo hold in a Ro-Ro vehicle carrier is normally divided horizontally into 3 or 4 separate enclosed spaces (vehicle spaces) and each space could include several cargo decks, which may be fixed or movable. A cargo hold could have about 11-13 cargo decks measuring at most approximately 200 m x 30 m. The depth from keel to the weather deck could measure about 30 m. The total cargo deck area could be in the region of 60 000 m^2. This means that it may take significant time for a first responder group or a fire group to reach any spot in the cargo hold.

Vehicles are loaded with minimum separation distances with enough space for lashing. After loading, only narrow access ways are left while most vehicles are stowed inside large "blocks" and are therefore not possible to physically access. Minimum horizontal clearances between passenger cars and structures are well specified and described in Table 32.

Table 32 – Minimum horizontal clearances between passenger cars and structures.

Bumper to bumper or ship structure	min. 300 mm
Side to side (outermost parts, e.g. folded side mirrors)	min. 100 mm
Side to ship structure	min. 200 mm
Clearance to key-car* door	min. 600 mm
Side or bumper to walkways or stairs	min. 600 mm
Roof to deck head	min. 100 mm

*) The key-car is a car to which the stevedores can have access and start/finish the loading sequence (the first car to be unloaded last car loaded on a cargo deck)

18.3.2 CO2 release aspects

This section is describing the CO2 activation aspects, while the system design is described in chapters 18.4.4 and 18.4.5.

The release of CO2 can be manually done directly in the CO2 room or in a centralized release panel in another space such as a fire control room or a safety control room. The system's pneumatically operated main valve and sectional valves are located in the CO2-room.

The CO2-release operation could be stressful and difficult since the detailed and rather complex instructions must be followed exactly for the correct release sequence and operation. This is because of the CO2's deadly effect to humans and that live training of activation onboard is normally not possible.

In order to ensure that the discharge is effective and cannot impose any hazards to crew members, a number of actions must be performed before the CO_2 system is activated. The sequence before and during activation is described below and the expected duration of each action is based on experience data from the fire drills onboard a ship.

Actions during fire drills daytime, at sea:

1. Time, from alarm, until the crew members are mustered at fire stations: 2-3 minutes.
2. Time required to pull on a fireman outfit: 4-5 minutes.
3. Time to perform assessment at the location where the fire was detected: 4-5 minutes.
4. Time to ensure that all doors are locked, ventilation is shut off, all crew members have evacuated and mustered in one location and counted: 3-5 minutes (however, this is normally done by team No. 2 during the time that team No. 1 is assessing the situation at the scene of fire).
5. Time required to switch on the CO_2 system: 5-6 minutes from when CO_2 system is ready to be used (upon completion assessment - item 3).

The total time from the fire alarm signal until CO_2 is released is estimated to approximately 15-18 minutes. It is estimated that additional time of about 3-5 minutes is required for gathering the crew at fire stations if the alarm is activated during the nighttime. The estimated 15-18 minutes should be considered as an ideal time to undertake activation and is based on a quick decision to release. In reality, experience indicate that CO2 is discharged some 20-30 minutes after the fire alarm.

In case of fire during port activities, additional time is required to evacuate both crew and stevedores, to verify that no one is left in the gastight zone and to close the large gastight doors such as quarter ramp or side ramp.

18.4 Design and production aspects

The vessel shall fulfil applicable prescriptive requirements regarding active and passive fire protection. The fire detection system, fire hydrants, fire hoses, portable fire extinguishers, foam applicators etc. are to be designed and positioned in accordance with SOLAS requirements.

18.4.1 Cargo decks

The cargo hold in a Ro-Ro vehicle carrier is normally divided horizontally into 3 or 4 separate enclosed spaces (vehicle spaces) and each space could include several cargo decks, which may be fixed or movable. An example is illustrated in Figure 30. Movable (or liftable) decks are divided into several deck panels that are individually adjustable in height.

The cargo decks located within a space are normally perforated for the numerous cargo lashing secure points and have large openings for rampways and clearances for movable decks. The internal decks are therefore by definition open for air flow and spread of gases and there is thereby no formal fire division between individual decks within a vehicle space. Each deck shall however have individual ventilation inlets/outlets, where the same ventilation duct can be used for several decks in the same vehicle space.

The horizontal and vertical boundaries consist of watertight divisions or A-class divisions.

Fire insulation of A-30 class is required for boundaries towards other vehicle spaces (A-0 for ships constructed before July 2014), accommodation spaces, and stairways. A-60 is required for boundaries between vehicle spaces and engine spaces of category A, while bulkheads may be A-0 subject that no dangerous cargo is stowed within 3 meters (SOLAS II-2/Regulation 9 Containment of fire 2.3.3.2.2 Note "f" in Table 9.5/9.6).

Movable deck panels are operated by dedicated vehicles, so called deck lifters, which adjust the deck panels to various positions based on the cargo, while liftable decks are normally wire operated with winches. Electrical cables for lighting fixtures, fire detectors, or for any equipment that needs power or other physical connections, have to be arranged with flexible guides and protectors.

Sometimes the notion "gas tight" is used to describe the boundaries between vehicle spaces. The understanding is that gas tight means the prevention of flow of hot combustion gases, smoke and CO2 between the spaces, but there is however no definition of gas tightness in SOLAS Ch. II-2 connected to space boundaries. The tightness of A-class closures is defined in the FTP-code related to the structural fire integrity where for "A class" divisions shall "be capable to prevent the passage of smoke and flame to the end of the one-hour standard fire test". However, they could not be guaranteed to be 100% gas tight. In relation to APV, gas tightness could have another meaning for EX-class enclosures.

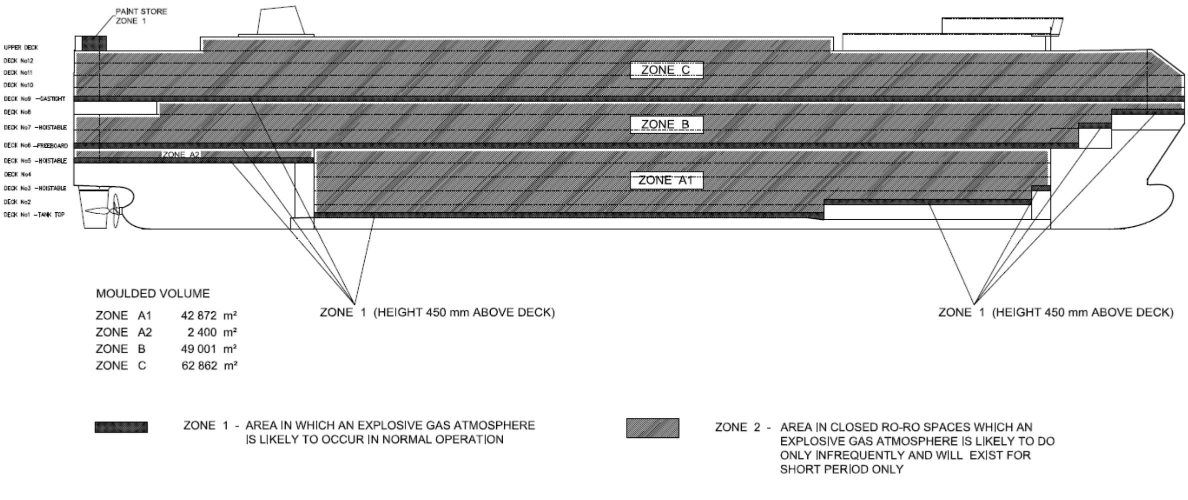


Figure 30. Cargo decks and gas tight zones (vehicle spaces) on a vehicle carrier – example.

18.4.2 Drainage system

On the lowermost deck of a vehicle space, a drainage, or scupper, system is arranged according the minimum requirements from Rules and Regulation, basically to handle the water from fire hoses.

Scuppers (piping about DN100) are arranged in the holds above the freeboard deck. An example of the scupper arrangement, where scupper positions are marked in red, is illustrated in Figure 31.

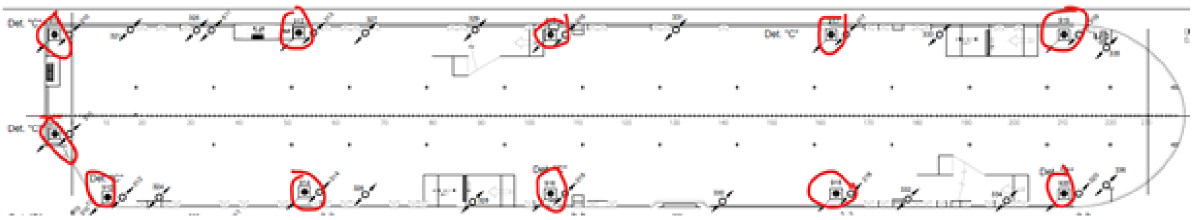


Figure 31. Scupper arrangement on a vehicle carrier – example.

In the cargo holds below the freeboard deck a bilge system is arranged (piping about. DN175). An example of the bilge system is illustrated on Figure 32.

If a fixed water-based fire-extinguishing system is installed, the drainage and scuppers must allow for the additional water capacity and screens or filters to prevent blocking of scuppers must be fitted (MSC.1/Circ 1320).

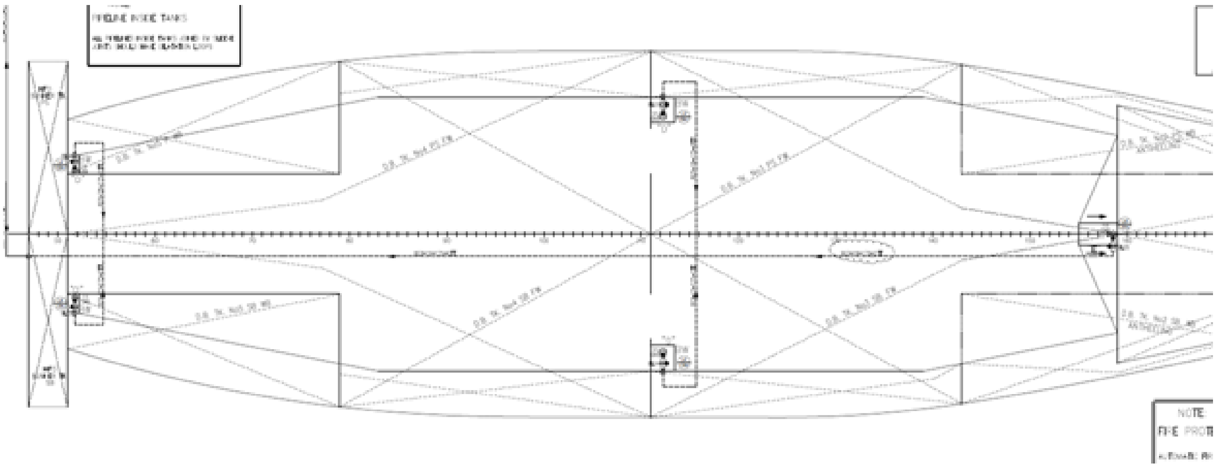


Figure 32. Bilge system in a lower hold of a vehicle carrier – example.

18.4.3 Structural arrangement

In a conventional steel ship design, a vehicle space deck is designed with steel deck plating stiffened by transversal web frames and longitudinal stiffeners. If not a boundary of a gas tight zone, the steel deck plating is fitted with lashing holes (abt. Ø50 mm - Ø80 mm) at a spacing according to the ship operator's requirement (for example 600 mm x 600 mm).

Every deck has a specified "clear height" depending on the cargo according to the ship owner requirement, and the clear height can vary for each shipowner. The clear height is a contractual item, and it is inspected in detail prior the delivery of the ship. The clear height means the available height for the cargo when the deck above is loaded (static load). In addition, the height between the theoretical deck lines includes the clear height, structure height, structure deflection (loaded) and building tolerance. Decks for the carriage of passenger cars have a typical clear height of 1900 mm -

2100 mm, decks for vans a clear height of 2100 mm – 2500 mm and decks intended for trucks or trailers a clear height of 4000 mm or more. An example of the clear heights in a vehicle carrier is presented in the Table 33 and illustrated in Figure 33. As indicated in the figure, decks 2, 4 and 6 are fitted with movable decks to allow the transportation of both passenger cars and larger vehicles.

Table 33. Structural and clear heights on different decks of a vehicle carrier – example.

Deck No.	Structural height mm	Clear height mm
1	2360	1900
2	2470	2100/4000
3	2460	2000/00
4	2470	2100/4000
5	2680	2000/00
6	3280	2900/3700/5300
7	2820	2500/1700/00
8	2420	2100
9	2420	2100
10	2220	1900
11	2220	1900
12	2220	1900
13 (Garage)	2200	1900

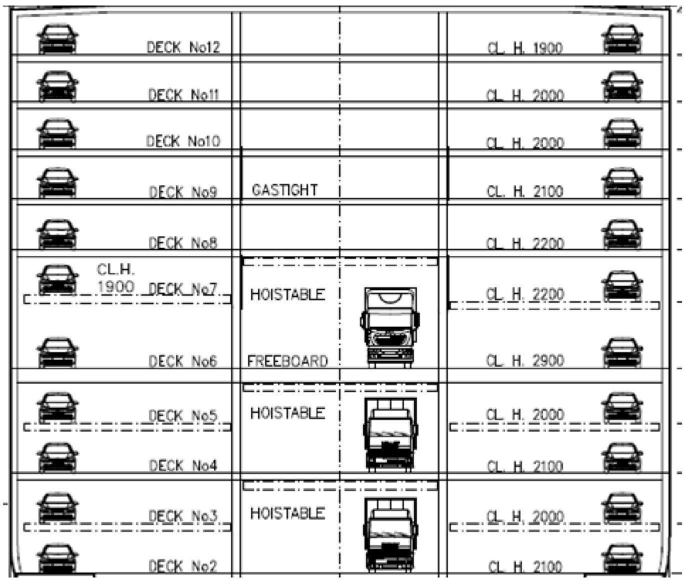


Figure 33. Clear height (CL. H.) - example

The example indicates that the clearance from the roof a passenger car to the underside of a structural member may be in the order of 100 mm to 500 mm, all dependent on the clear height of the deck and the actual heights of the typical passenger cars.

18.4.4 Fixed firefighting systems

18.4.4.1 General

The most common type of fixed fire-fighting systems on vehicle carriers is the low pressure CO_2 system. Low pressure CO_2 systems are designed to maintain the carbon dioxide supply at around -18°C in an insulated, refrigerated pressure storage unit. The advantage of a low pressure system is that one single tank can be used instead of a large number of high pressure CO_2 cylinders.

SOLAS allows for fixed water-based fixed fire-extinguishing systems, such as water mist systems, but these have not had any bigger impact in the industry so far, mainly due to the high cost and the increased installation complexity compared to CO_2.

Fixed foam deluge systems are being used in some vehicle carriers.

Focus in this chapter is on the CO2 systems.

18.4.4.2 CO_2 low pressure systems

The system capacity is typically in the range of 30-50 tonnes of liquefied CO_2 stored in one or two insulated free standing storage tanks in a separate CO_2 space, normally located on upper deck. The CO_2 capacity is determined as sufficient for a single discharge into the largest protected space, normally one of the vehicle spaces. CO_2 is normally also used for engine spaces and other spaces that need protection, while such spaces usually are much smaller than a vehicle space.

As a fire-fighting system on vehicle carriers, it is effective, relatively inexpensive and easy to install at a shipyard. Even though there are multiple decks in a vehicle space the CO_2 piping and nozzles are normally located only at the top or sides of the space, not on each deck, which simplifies the installation, especially for movable decks where flexible hoses can be avoided.

A low pressure, total flooding CO_2 gas fire-extinguishing system shall comply with the applicable prescriptive requirements in SOLAS and in the Fire Safety Systems Code [Ref IR04.1]. It is thus designed based on the following requirements:

- For vehicle and Ro-Ro cargo spaces the quantity of carbon dioxide available shall, unless otherwise provided, be sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the largest cargo space so protected in the ship. This corresponds to an oxygen concentration of about 11.5%.
- At least 67% of the CO_2 amount to be released within 10 minutes, corresponding to 100% within 15 minutes.

18.4.4.3 Design

The storage tank(s) is supplied with a manual main (stop) valve, normally open, and a pneumatically operated main valve, normally closed. Each protected space has its own section valve, also pneumatically operated. Branch pipes are led to each protected space and fitted with a sufficient number of nozzles.

The system is fitted with two redundant cooling compressors fed from the emergency switchboard.

Discharge of the total flooding system may be done from two positions, either on the release panel in the CO2 room, or from a mirrored remote control panel located in a Control Station such as a Safety control room or Fire control room. A distinctive CO2 visual and audible alarm is activated in the protected spaces as soon as the release cabinet is opened.

Optionally, some vessels have a connection from the fire main line to the CO2-system in order to have the possibility to use sea water as cooling media after the release of CO2. In DNV GL this is a requirement for their class notation F-C.

18.4.5 Specific safety aspects

18.4.5.1 CO_2's inerting effect on battery fires

If used in fires including electrical APV's, CO2 is in theory maintaining its inerting effect and would thereby prevent the fire from spreading in combustible materials. But since there is limited cooling effect by CO_2, a Li-ON-battery under thermal runaway would not be controlled. Further, an overheated or damaged battery could still be a risk object after the fire in combustible materials has been extinguished. As long as the space boundaries are intact, the inerting effect would in theory be maintained. There are however no known research studies done regarding this inerting effect over time, considering that damaged batteries could possibly self-ignite hours or even days later.

18.4.5.2 Compressed gas vehicles

A fire in or close to an APV compressed gas vehicle means a risk for heating of the gas tank to a temperature level so that the safety valve is opened. If the released gas is immediately ignited this could result in a jet flame which means a high risk to first responders or fire fighters. A jet flame could potentially also make the fire spread faster to the surrounding cargo, depending on the direction and range of the flame. If the gas is not ignited immediately, or if the jet flame is extinguished, there is a risk that the gas would cause a deflagration or even an explosion, which in turn could destroy the enclosed space boundaries.

If the safety valve fails to open, there is a risk for a pressure vessel explosion.

Quick action to limit a fire and cool down the gas tank and thereby reducing the risk for a safety valve release, or even a tank explosion, is most important.

18.4.5.3 Protection of adjacent spaces

For vehicle carriers constructed before July 2014 there are no requirements for fire insulation between vehicle spaces. From July 2014, A-30 is required for both decks and bulkheads between vehicle spaces. As various studies and experience show, a passenger car fire would emit heat to ignite tyres on a deck above within approximately 10 minutes, for a deck structure with A-0 rating. That means that if a fire breaks out on the uppermost deck in a vehicle space, the fire could spread to the adjacent space before CO2 has been possible to be released, due to the complexity in the release operation. If that happens, the amount of CO2 will not be sufficient for both spaces. To prevent such a scenario, the above boundary of an un-insulated vehicle space should be cooled down in order to prevent fire from spreading and then to maintain the cooling until the temperature is below critical levels. Alternatively, a supplemental (to the CO2 system) automatic water-based fire protection system may cool combustion gases to prevent fire spread from the space with the fire to adjacent spaces.

While A-30 class insulation is mandatory for new vessels, the boundary cooling is by definition less critical than for A-0. Boundary cooling would anyhow enhance the safety since the temperature rise even with A-30 could go faster than 30 minutes, depending on the fire intensity and the thickness of the deck plating.

If the fire includes electric APV, or if APV's are stowed in adjacent spaces, the boundary cooling would have to be maintained for a longer period than for ICE-vehicles

18.5 Alternative design aspects

This chapter is intended to describe the analysis of the impact of additional weight performed during the design of a vehicle carrier delivered at Uljanik shipyard (2017) with composite car decks instead of steel decks. The alternative design assessment has been performed by RISE. More information available at Ref. [16]. The vessel is of the dimensions and capacity similar to the LASH FIRE vehicle carrier generic ship.

As the composite deck design was the first such design (and still is!!) in the cargo shipping industry, there were quite a lot of uncertainties from the ship operator and the shipyard. Even if the design of the composite decks was adjusted so Alternative design procedure according to SOLAS prescriptive rules was not required, in the agreement with the ship owner, the assessment and modifications (minor modifications) of the design to reach equivalent safety have been performed. During the design phase, alternatives have been considered to the prescriptive minimum requirements for the fire extinguishing system. One of them was assessing the installation of a drencher system in addition to the CO2 system in the uppermost vehicle space of about 25 500 m2 cargo space area (from total three vehicle spaces, about 58 000 m2 cargo area) as it has been proven that water is excellent in composite fire distinguishing (RISE experience). The results showed the addition of 70 tons of piping and additional cost of EUR 1. 500 000, which has been considered as not feasible. For the considered vehicle carrier, this additional weight load in the ship means an additional weight (2.5x the added weight) of ballast water to obtain the stability requirements. Resulting in a total loss of deadweight of about. 245 tones, and an increased fuel consumption for the same cargo weight of 2% (abt. 1 ton of fuel per day). In this case, the additional weight has not only impact on the investment cost but also on the operational cost.

In the LASH FIRE case, the additional system is intended to be installed in all cargo holds, where a large area shall be covered by the system, which is a challenge even with a light weight and low capacity system. The additional weight would, however, have less impact on the stability of the ship but more impact on the deadweight.

18.6 Environmental aspects

The fire suppression media of the novel system shall not be toxic to the environment as it can be released to the atmosphere through the ventilation system and other openings (doors) and to the sea through the drainage system.

18.7 Proposal for development and restrictions

The proposals for the development and restrictions from operational and design aspects and few conceptual solutions are listed below:

- The new system shall be designed to reduce the additional weight and cost as much as possible.
- The new system shall be designed in order to avoid interference with the cargo area i.e. not to reduce the available cargo parking area and free heights.
- The new system shall be designed in order to avoid interference with the passageways for cargo and crew.
- The new system shall be of dry-pipe design, in order to not cause cargo damage due to leakage.
- The new system shall be possible to operate on hoistable car decks.

  - *"The presence of obstructions and the potential for shielding of the water spray should be evaluated to ensure that the system performance is not affected. Supplementary sprinklers or nozzles should be installed beneath obstructions. In addition, nozzles should be located to protect spaces above and below intermediate decks, hoistable decks and ramps. Nozzles below hoistable decks should be capable of protecting all applicable heights."*
  - **[MSC.1/Circ. 1430/Section 3.21]**
- The new systems shall be possible to operate in winter conditions, based on the vessels intended operation area.
- The new system performance shall be considered for both seagoing and harbour conditions (loading and unloading operations).
- The new system shall be suitable for boundary cooling towards adjacent spaces. System add-ons to be investigated in order to distribute water over other areas other than over the fire even if the system complexity is increased.
- The new system shall be designed to run continuously for a prescribed minimum period of time and should be possible to connect to the sea water connection for prolonged duration.
- The new system shall be designed to be released in one or several sections and on different deck levels, simultaneously. A rough idea on a deck section area is approximately 12x12 m (based on 3x3 cars) and that the system shall be possible to be activated in approximately 8 sections simultaneously (worst case with a fire spot requiring 4 sections and simultaneous release on the next deck above the fire.
- The new system shall be possible to activate both automatically and by a centralized release panel.
- The new system shall be possible to use simultaneously with manual fire-fighting actions.
- The new system performance shall be considered versus APV's.
- The new system shall be possible to install both in new and existing ships.
- The new system performance may be considered versus alternative structural designs with composite materials introduced.
- The new system shall be designed according to shipbuilding/marine standards with all relevant approvals and certificates.
- The new system shall be designed to be robust, reliable and to require minimum maintenance.
- The new system shall be designed to eliminate clogging of nozzles.
- The new system shall be designed to minimise the maintenance cost.

19 Weather deck fixed fire-extinguishing systems - Action 10-B

Main author of the chapter: Goran Pamic, FLOW

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 10-B i.e. Weather deck fire extinguishment.

19.1 Short Description of the addressed Action

The goal of the Action 10-B is to develop and demonstrate feasible and effective fire-extinguishment solutions for weather deck, throughout the following tasks:

- Definition of conditions for use of weather deck fire extinguishing systems
- Development of fixed weather deck fire-extinguishing systems by system suppliers
- Large-scale fire performance validation of selected weather deck fire-extinguishing systems
- Onboard demonstration and testing of selected weather deck fire extinguishment solutions Regulation Review

19.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

19.2.1 General

19.2.1.1 Scope

This section aims at giving an overview of the requirements applicable to ro-ro spaces regarding Action 10-B i.e. “weather deck fixed fire-extinguishing systems”.

19.2.1.2 Applicable regulations

The present review is based on currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

Table 34. List of documents used for the review of regulations for Action 10-B

IMO Documents	SOLAS Convention, as amended
	IBC Code, as amended
	IGC Code, as amended
	MSC.1/Circ.1615, “Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships”
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
	DNVGL Rules for the Classification of Ships, January 2017
	LR Rules and Regulations for the Classification of Ships, July 2016
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 28/12/17 edition
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

19.2.2 Requirements

In general, SOLAS [5] includes very limited fire protection requirements applicable to weather decks where vehicles may be stored. Especially, no fixed fire-extinguishing system is required in such areas.

SOLAS II-2/20

Traditionally, SOLAS [5] includes very few cases where fixed fire-extinguishing systems are required on weather decks, both because the risk of fire has often been considered limited and because it was deemed impracticable.

More recently however, it is to be noted that IMO Interim guidelines MSC.1/Circ.1615 [11] for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships recommends that a fixed fire-extinguishing system, e.g. water monitors, be provided on weather decks intended for the storage of vehicles on passenger ships.

MSC.1/Circ.1615 §3.4

At this stage, this recommendation is goal-based and not fully defined. Member States are invited to bring the Interim guidelines [17] to the attention of all parties concerned and to recount their experience gained through their use to IMO. In order to be easily and uniformly applicable, the following aspects would be worth precising:

- Requirements for the capacity of the system:
    - Required flowrate;
    - Covered area, length of throw of the monitors, minimum number of monitors; and
    - Number of monitors required to work simultaneously;
- Extinguishing medium: sea water, fresh water, foam… In the last two cases, an expected functioning duration is needed to size the tanks for the extinguishing medium;
- Pumping redundancy requirements;
- Material and component approval requirements;
- Drainage system – already mentioned in MSC.1/Circ.1615 [11]; and
- Monitoring and control requirements for the whole system, including monitor orientation and operation, pump and valve controls.

19.2.3 Other regulations

This section lists regulatory references for weather deck fixed fire-extinguishing or water-based systems not directly applicable to vehicle weather decks, but which could be used in order to propose solutions that might be relevant for Action 10-B.

Weather deck monitor systems can be found on:

- Fire-fighting ships. Such systems are not covered by IMO regulations but specifications can be found in Class Rules, e.g. BV NR467 Pt E, Ch 4, Sec 3, [7], [11] and [17].
- Ships constructed on or after 1 January 2016 designed to carry containers on or above the weather deck as per SOLAS II-2/10.7.3 [1]. In the relation to the aforementioned SOLAS paragraph, more details about mobile water monitors can be found in MSC.1/Circ.1472[22]; and
- Containerships with reinforced fire protection measures, as described in BV ECFP (Enhanced Cargo Fire Protection for Container Ships) additional Class notation, BV NR467 Pt F, Ch 11, Sec 30 [3.5] (ref. [18]). This class notation comes as a complement of SOLAS requirements mentioned above.

Other systems installed on open decks include:

- Water-based cooling systems installed in the cargo area of liquefied gas carriers, as specified in IMO IGC Code 11.3 [19];
- Dry chemical powder fire-extinguishing systems installed in the cargo area of liquefied gas tankers, as specified in IMO IGC Code 11.4 [19];

- Fixed deck foam system required in the cargo area of chemical tankers, as specified in IBC Code 11.3 [20];
- Fixed foam fire-extinguishing systems required for helidecks as per SOLAS II-2/18.5.1 [5] and IMO FSS Code Ch.17 [21].

Finally, it can be noted that the outer surface of superstructures facing high fire risk external areas may be protected by:

- A-60 fire insulation on oil tankers, as per SOLAS II-2/4.5.2.2 [5] and on chemical carriers, as per IBC Code 3.2.3 [5];
- A-60 fire insulation and self-protection water-spray systems on liquefied gas carriers (IGC Code 3.2.5 and 11.3 [19]); and

A-60 fire insulation or self-protection water-spray systems on fire-fighting ships (NR467 Pt E, Ch 4, Sec 4 (ref. = [17])).

19.3 Operational aspects

According to Rules and Regulation, there are no requirements for Weather deck fixed fire-extinguishing system. The implementation of such systems is therefore a decision left for the ship operators. As such, only a system that can guarantee a significant step up in the protection of cargo and lives, but at the same time be cost-effective and not decrease the space on cargo decks will motivate ship operators to install it.

The challenges for a fire suppression system on a weather deck include a very high fire load due to tightly packed vehicles, open areas with unlimited supply of air (oxygen), limited access on deck to a potential source of fire, etc. The automatic fire detection on weather decks is as well not regulated and mainly depending on manual detection, as described in Chapter 15.

In regulatory process following the FIRESAFE studies aiming for SOLAS 2024 amendment following requirements on fixed weather deck detection are proposed in IMO SSE7 Fire Protection Correspondence Group, but not decided:

"4.1.2 In passenger ships, a fixed fire detection and fire alarm system shall be provided for the area on weather deck of passenger ships intended for the carriage of vehicles. The fixed fire detection system shall be capable of rapidly detecting the onset of the fire anywhere on the weather deck area. The type of detectors and their spacing and location shall be to the satisfaction of the Administration, taking into account the effects of ventilation, cargo obstruction and other relevant factors. Different settings may be used for specific operation sequences, such as during loading or unloading and during voyage, in order to reduce the false alarms."

For weather deck detection requirements see Chapter 15.

The weather deck also carries the dangerous cargo, increasing the probability for a fire, and the propagation of fire is a risk to consider due to the tightly packed cargo.

Common fire-protection on ro-ro weather decks include sea water system fire hydrants and portable fire-fighting equipment - powder fire extinguishers and foam applicator units, as illustrated on Figure 34. Typical weather deck arrangement on a ro-ro cargo ship is illustrated in Figure 35.

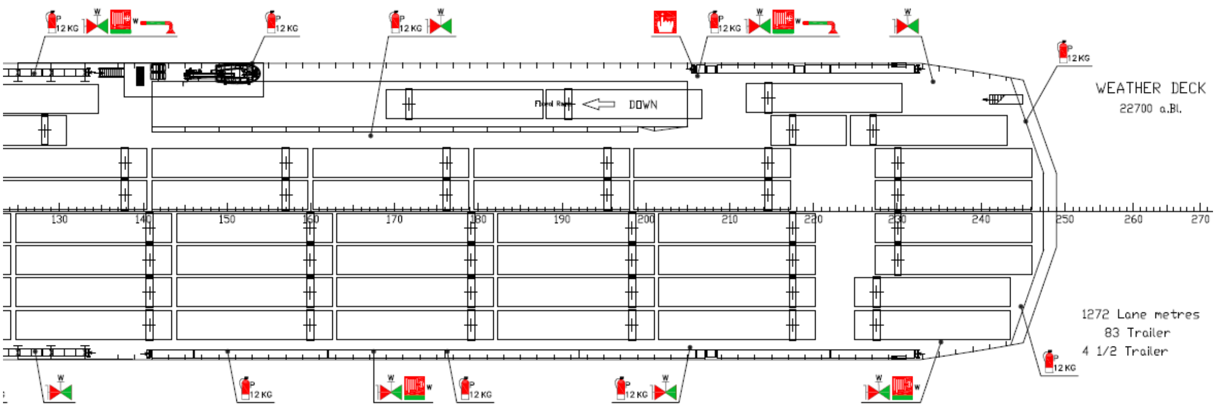


Figure 34. Magnolia Seaways – Fire-protection appliances plan (Weather deck detail)

Figure 35. Magnolia Seaways – Weather deck view

Additionally, fire monitors can be installed on ro-ro and ro-pax ships, where the design of a weather decks allows an elevated position for the installation. Example of a fire monitor installation is illustrated on Figure 36. More examples are shown in Annex A and Annex B.

Fire monitors are to be located in a "safe location" for manual operation, or remotely operated. If no safe locations can be achieved, manually operated monitors may be located with overlap coverage where at least one shall be available. Other possibility, if the primary objective is boundary cooling, is to have a remote water flow control and that the monitors are locally opened in a pre-set throw configuration.

Figure 36. Stena Jutlandica - Weather deck Fire monitor

There are shipowners that have already installed fire monitors on weather decks. Coverage may not be 100% but close to. These installations are either with remote control or manually operated. Both are suitable depending on ship layout.

Note that there are ships with very large weather decks and almost no superstructure to fit monitors in. Too prescriptive requirements on location, cross coverage, coverage from two or more directions, redundancy, even full coverage may not be practically possible to implement. A ro-pax ship with limited possibilities for location of monitors is illustrated on Figure 37. She has a 135 m long weather deck arranged where only one position for fire monitors in the aft part is structurally suitable, unless specific structures are designed and installed for the fire monitors

Also, there are designs with no superstructure in the aft part of the ship which shall be considered when designing systems, evaluating systems and also when setting requirements for the systems/rule making.

Figure 37. Ro-pax with large weather deck aft

Depending on layout of the ship it may be important to protect the full area of the ships weather deck with fixed fire-extinguishing systems. Fires on weather deck seldom (or never) lead to total loss of the ship or evacuation. Heat and smoke are vented away quite efficiently. In several designs a weather deck or part of it could be allowed to burn quite heavily without causing any severe damage to other parts of the ship. Focus for weather deck fire-extinguishing systems could be on protecting from fire spread and protection of vital safety functions, rather than full focus on extinguishing every square meter of the deck area.

19.4 Design and production aspects

Generally, cargo decks are designed to maximise the area for cargo stowage. This is emphasized on weather decks, thus limiting the available area for ships equipment and systems. Therefore, the impact of the novel fire-fighting systems on the cargo area should be minimized.

The system should be designed in such manner to cover sufficient cargo area (preferably full coverage) granting the access of the extinguishing media to the fire source (preferably any location), considering obstacles such as cargo. The cargo is stored close to each other, where the hight of cargo (for example trailers or special cargo) can even more limit the access to the fire source and thus the risk of fire propagation can be increased. It should also be empathised that heavy weather conditions as strong wind a large waves could influence the possibilities for water reaching a fire.

The absence of structure above a weather deck minimize the installation possibilities of a fire-fighting system. Therefore, a deluge (drencher) system with a grid of open nozzles above the protected area would require adequate supporting structure which could affect the ship parameters (reduced cargo area, limiting, increased ship weight, high installation and maintenance cost, etc.). Further, a deluge system would require water flow rate pump capacity for the simultaneous activation of at least two sections.

The system should have enough range and power from appropriate numbers of positions onboard, at heavy weather conditions for an effective fire-extinguishment i.e. to suppress or contain a fire and to cool down adjacent boundaries to limit structural damage.

Any fixed fire extinguishment system shall be preferably designed to:

- avoid interference with the cargo loading routes and stowage area,
- minimise the obstacles for the ship's visibility from the command bridge.
- be robust, possibly standalone or with limited bracing to the surrounding structure
- for harsh environment, including ice accretion, saltwater spray, fog, direct sun etc. heavy corrosion potential, high temperature amplitudes, with the possibility of drainage to prevent freezing
- minimise the effect on the stability of the ship, adequate drainage of media (water) from the deck must be ensured
- Be simple to operate
- Discharge the extinguishing media immediately after activation
- Provide the desired performance objectives in terms of fire suppression, fire control and fire containment
- Be manually operated or if, automatically operated, have features that prevents or limits the probability for false activation
- Be able to handle different types of fires (electrical, flammable liquid spills, IMDG goods etc.)
- Be class approved and fulfil any IMO standards
- Take up as less as possible space on the vessel
- Preferable not have the option of running out of extinguishing medium, and if running out of supply be capable of continuous operation using sea water
- Safe for humans and marine environment
- Preserve vessel, cargo, and equipment as much as possible
- Able to reach the fire with minimum time delay when activated
- Possible to activate remotely
- Possible to activate if electricity fails, i.e. have redundant means for power supply
- Be easy to inspect, control and maintain
- Number of equipment and sub-equipment to be kept to a minimum
- Easy to include full scale in fire-drills
- Intuitive and simple to operate
- Be reliable and not cause faults and/or delays in activation
- Be easy to clean up after when the fire is extinguished
- Not limit crew access to the section where the system is activated
- Provide easy overview of where the system is activated
- Be easy to shut down and re-start if required

Automatic solutions should be taken into consideration as a next step in the evolution of weather deck fire protection systems, however this comes in a close correlation with fire detection systems on weather decks with all aspects and challenges of such system, as described in Chapter 15.

Means of fire-extinguishing systems on weather decks with the possibilities of activation and control/operation of such systems (fire monitors and CAFS) from a secured position should be taken into consideration during development. Robotic nozzles that automatically guides/points to the source of fire should be considered, but individual monitors, should always have provisions for manual activation and remote control (i.e. have a manual override).

19.4.1 Drainage system

Drainage of extinguishing media from the deck shall be considered as to prevent the effect upon stability of the added weight and free surfaces.

There is no specific calculation requirement for the drainage system on weather decks available. Rules and regulations for drainage system in ro-ro spaces and fitted with a fixed pressure water-spraying fire-extinguishing system, may be considered, see excerpt from BV Rules below (Ref. BV RULES NR467/Pt C, Ch 1, Sec 10, Article 8):

- *In such case, the drainage system shall be sized to remove no less than 125% of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles, taking into account IMO Circular MSC.1/Circ.1320.*
- *Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.*

Further, weather decks shall be arranged with “freeing ports” (Ref. BV RULES NR467/Pt B, Ch 8, Sec 10, Article 6). Those are openings arranged on the side bulwark to enable a rapid discharge of the green loads from the weather deck. Green loads are sea water loads on exposed deck due to wave impact at extreme weather conditions The minimum required area of the openings depends on the deck arrangement, opening arrangement (vertical position i.e. distance from deck), etc., where the (vertical) discharge/drainage is not to be considered in the calculation. Generally, the lower edge of such openings shall be as close as possible to the deck.

Weather deck drainage and freeing ports arrangement shall especially be considered for “confined” weather decks arrangements such as at Stena Jutlandica, illustrated on Figure 36.

A common drainage arrangement on a ro-ro weather deck considers scuppers/piping of DN80 to DN150 arranged along the deck borders at a distance of about 30 m, and parts of the deck where water pockets may occur. Further, larger piping diameters may be arranged on the deck ends (aft/fore). A typical drainage arrangement on a ro-ro weather deck is illustrated on Figure 38.

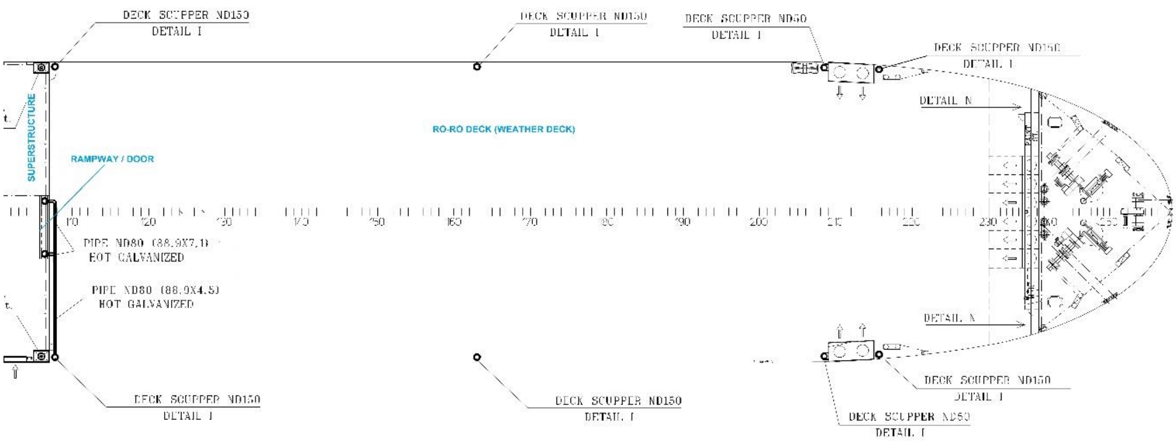


Figure 38.Typical ro-ro weather deck drainage arrangement

The drainage line is led to the outer shell where the liquids from the deck are discharged into the sea. The scuppers may be arranged with plugs to prevent the spill of oil or fuel from the ro-ro cargo units into the sea. If fitted, the plugs are used in harbour or other “no-spill” zones according to the ship operator, flag state or harbour requirements. Typical detail is illustrated on Figure 39.

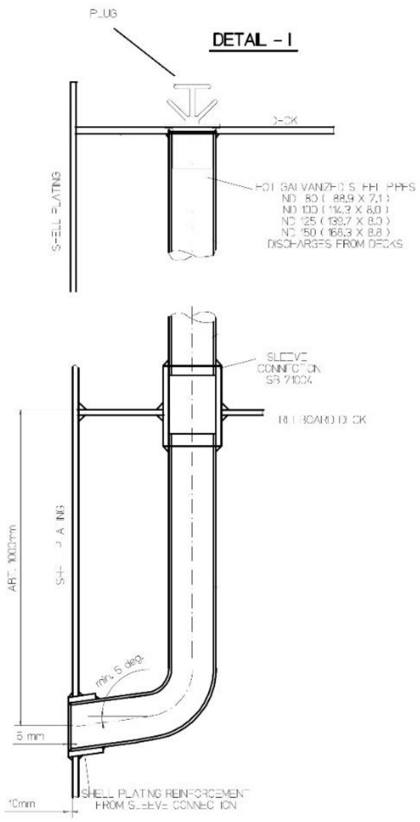


Figure 39. Typical Scupper detail on a ro-ro weather deck

19.5 Environmental aspects

During the extinguishing of a fire on a weather deck, large quantities of extinguishing media mixed with fire by-products gets released into the environment. The medium used to extinguish fire should not be harmful to human or marine life to the extent similar to the requirement for other parts of the ship. In example, fire-fighting water and media from other decks also gets released to environment. It is important that the same requirements are applied throughout the ship and no special requirements are introduced only for weather decks.

19.6 Proposals for development and restrictions

Purpose with the system should be established: Extinguishing or contain fires on weather deck and provide boundary cooling of other spaces (roro spaces below, roro spaces forward/aft, accommodation, funnel casings, etc.). Extinguish fires on a certain part of the deck but allow for other/minor/less prioritized areas to burn.

Deck area is not a square box, there are always irregularities and perhaps minor hidden/less accessible parts.

Superstructure may not always be present. This will require that certain fire monitors may need to be installed on dedicated supports to obtain full coverage of the deck area. Such supports may be challenging to realize due to vibrations, high strain location and without interfering with cargo capacity and operation.

If water is to be used, it should preferably be corelated with the installed drencher capacity, being able to use the same pumps.

It could be interesting to consider a floor-mounted sprinklers system on a weather deck, as a separate system or in combination with other systems, preferably integrated with other ship system. Such solution could reduce the potential for a fast fire spread and partially pre-wet vehicles. One of the possibilities could be a water-based sprinkler system with vertical sprinkler nozzles placed on the floor between the lanes, thus forming a water barrier between lanes and retarding the propagation of fire. Such system could be divided into zones on deck, installed beneath the deck, with manual or automatic activation. Transverse line(s) of sprinklers could mean an even more effective way of isolating the fire source; however such solution could affect the cargo arrangement (avoiding parking above those transverse lines) potentially reducing the cargo area and increase the installation and maintenance cost.

The nozzles itself should not rise above the floor (i.e. pop-up nozzles) and special attention should be put on the nozzles to avoid clogging by dirt and to be easy cleanable. The design of the nozzle itself should allow only a vertical spray of water between the lanes not to waste water under vehicles.

Further, fixed nozzles mounted on vertical structures can be considered, where the purpose would be either to cool vertical structures or throw water onto deck.

Fire-fighting systems with heavy duty drones could be a feasible solution, where the drone could adjust the position and target the fire source from the optimal direction and thus increasing the fire-fighting system performance. Drones could be combined with other fire-extinguishing systems such as fire monitors or others reducing the total amount of equipment. Further, drones can be used for detection as well as. Currently, available solutions on the market, where drones are used for similar application, are used for washing, de-icing and maintenance of wind turbine parts (blades, tower, drainage holes, etc.) but also fire-fighting as shown on Figure 40 and Figure 41 (source: https://www.aerones.com/, https://www.fireapparatusmagazine.com/2017/01/12/aerones-firefighting-drone/#gref).

Fixed water curtain system (or use of monitors to achieve fire curtain function) for use at aft opening from an open ro-ro space shall be considered. An example of a fire curtain installation is shown in ANNEX I.

Regarding the extinguishing media, fluorine-free and bio-degradable foam agents can reduce the impact on the water pollution. The use of it in a CAFS to be considered if applicable.

Figure 40. Heavy duty fire-fighting drone (1)

Figure 41. Heavy duty fire-fighting drone (2)

20 Updated performance of alternative fixed fire-fighting systems - Action10-C

Main author of the chapter: Vito Radolovic, FLOW

This chapter relates only to the action challenge (see title) or solutions expected to be developed.

Vehicle space aspects on ro-pax, ro-ro cargo and vehicle carriers where water-based fire-fighting systems can be arranged are considered in this chapter

20.1 Short Description of the addressed Action

The goal of the Action 10-C is to establish a harmonized performance level for alternative fixed water-based fire-fighting systems for ro-ro spaces and special category spaces through:

- Literature study for alternative fixed water-based fire-fighting systems
- Development of a relevant fire test standard for alternative fixed water-based fire-fighting systems intended for ro-ro spaces and special category spaces
- Large-scale validation of the new fire test standard for alternative fixed fire-fighting systems

20.2 Operational aspects

Generally, it is expected that realistic fire test standards are set to establish realistic performance objectives, and so to improve fire safety on ro-ro vessels, and to avoid over-design of the fire-fighting systems which could unnecessarily increase the complexity and lifecycle cost of the system.

In this report, the environment within ro-ro spaces is described, including a description of the ship's structure and equipment as well as cargo type categories and stowage arrangements.

20.2.1 Realistic fire scenarios

Realistic fire scenarios can be based on the fire investigation reports. Related information is available in the LASH FIRE Deliverables:

<u>Accident investigation reports:</u>

- Description of fire sources and how the cargo will affect the fire response can be found in the LASH FIRE Deliverable D04.1
- Description of consequences (for risk model) can be found in LASH FIRE Deliverable D04.3
- The list of public accident investigation reports can be found in LASH FIRE Deliverable D04.2 Annex A.

Further, Marine Incidents/Near Misses data was collected from MOAG.

It is to be noted that the information provided shall be considered carefully, as a guidance only, as not all accident reports are available.

List of fire scenarios should also include AFV related fires that may be faced now and in future and may not be found in historic sources. Both light and heavy AFV units to be considered.

20.2.2 Cargo

In this chapter relevant information on the cargo is given, such as cargo type categories, minimum cargo distances in stowed position and illustrations of typical cargo stowage. Detailed descriptions of the cargo and stowage can be found in the LASH FIRE Deliverable D08.1.

20.2.2.1 Cargo type categories

Indication of the cargo type categories on ro-pax, ro-ro cargo and vehicle carriers are listed below.

Ro-pax ships

- Passenger cars, vans, campers, including APVs[20],
- Trucks, semitrailers and trailers, including APVs
- Refrigeration/heating units (Reefers), including APVs
- Classified goods (IMDG and ADR), including APVs
- Special cargo (non-typical vehicles or units such as ROLL TRAILERS, excavators, etc.), including APVs
- Containerized cargo

Ro-ro cargo ships

- Passenger cars including APVs, vans, campers
- Trucks, semitrailers and trailers, including APVs
- Refrigeration/heating units (Reefers) , including APVs
- Classified goods (IMDG and ADR) , including APVs
- Special cargo (non-typical vehicles or units such as ROLL TRAILERS, excavators, etc.), including APVs
- Containerized cargo[21]

Vehicle carriers

- Passenger cars, vans, campers, including APVs
- Trucks, buses, semitrailers and trailers[22]
- Railcars and tramways
- Construction and mining equipment, machinery, power equipment
- Boats, aircraft parts
- Breakbulk
- Classified goods (IMDG and ADR)
- Special cargo (non-typical vehicles or units such as ROLL TRAILERS, excavators, etc.)

20.2.2.2 Distances between cargo

On ro-pax and ro-ro cargo ships cargo is (mainly) stowed in lanes, including passenger cars, trucks, trailers and other. Typical cargo stowage is illustrated in Figure 42 to Figure 47.

[20] Alternative Powered Vehicles (APV) is a group name for vehicles that use either pure batteries (Electrical Vehicle, EV) or some type of gas such as: Compressed Natural Gas (CNG), Liquid Petroleum Gas (LPG), Liquid Natural Gas (LNG) and Hydrogen as primarily energy source, pure or in combination with other energy storage such as batteries or diesel/gasoline. These vehicles that use gas are to be treated differently than hybrid solutions that combines diesel/gasoline with batteries.

[21] Containers are commonly carried on deep sea ro-ro ships by forklift and on short sea ro-ro ships they are caried on roll trailers

[22] Trailers and semitrailers are not common on deep sea ro-ro ships and vehicle carriers

On vehicle carriers the cargo is, in general, oriented longitudinally in lanes, but can be also parked in transversal direction to maximize the number of loaded cargo units. Typical cargo stowage is illustrated in Figure 48 and Figure 49.

Typical minimum horizontal and vertical clearances between cargo unis and ship structure/equipment are shown in Table 35, Table 36 and Table 32. It is to be noted that in a real stowage scenario, the specified distances may vary from those specified.

Table 35 – Minimum horizontal and vertical clearances between passenger cars and structures on ro-pax ships.

Bumper to bumper or ship structure[23]	min. 300mm
Side to side	min. 500 mm
Side to ship structure	min. 400 mm
Side or bumper to walkways or stairs	min. 300 mm
Roof to deck head[24]	min. 400 mm

Table 36 – Minimum horizontal and vertical clearances between trailers and structures on ro-pax and ro-ro cargo ships.

Bumper to bumper or ship structure[25]	min. 200 mm
Side to side	min. 200 mm
Side to ship structure	min. 400 mm
Side or bumper to walkways or stairs	min. 200 mm
Roof to deck head[26]	min. 300 mm

Table 37 – Minimum horizontal and vertical clearances between passenger cars and structures on vehicle carriers and ro-ro cargo ships.

Bumper to bumper or ship structure	min. 300 mm
Side to side (outermost parts, e.g. folded side mirrors)	min. 100 mm
Side to ship structure	min. 200 mm
Clearance to key-car[27] door	min. 600 mm
Side or bumper to walkways or stairs	min. 600 mm
Roof to deck head	min. 100 mm

[23] Depending on the season, can vary from 300 mm to 600 mm

[24] can vary from 400 mm - 800 mm

[25] can vary, where for self drivers from 400 mm – 1500 mm, unaccompanied from 200 mm – 3000 mm

[26] can vary, from 300 mm – 600 mm

[27] The key-car is a car to which the stevedores can have access and start/finish the loading sequence (the first car to be unloaded last car loaded on a cargo deck).

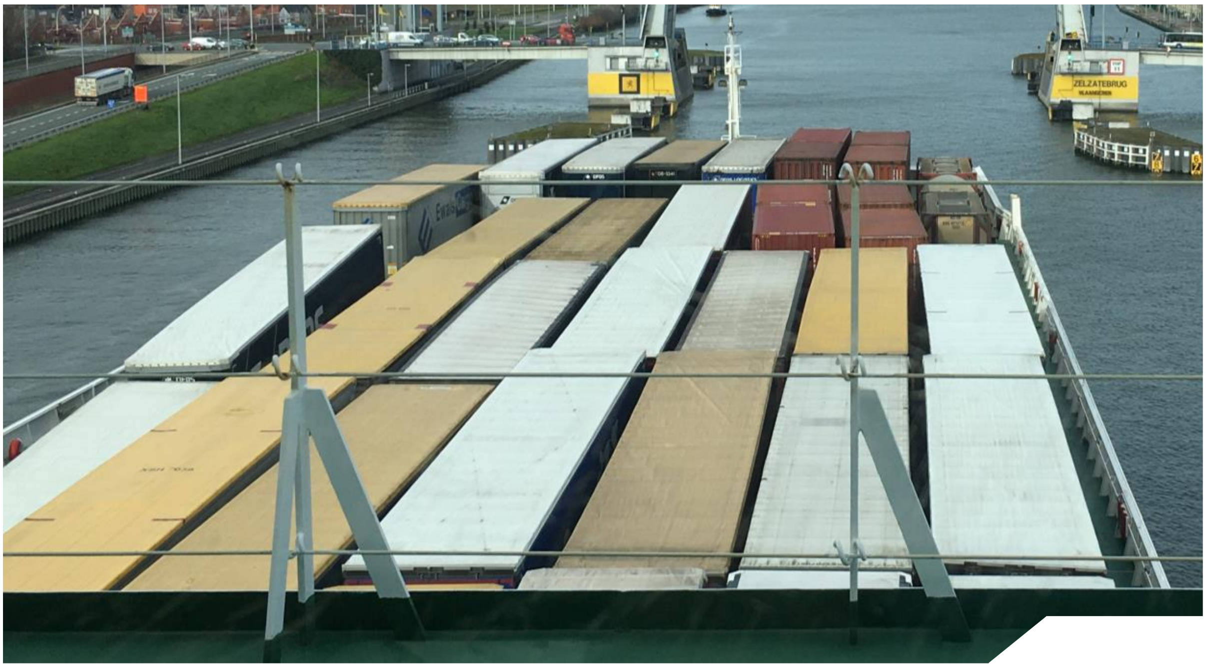


Figure 42. Full loaded weather deck on a ro-ro cargo ship

Figure 43. Example of loading on a ro-pax ship

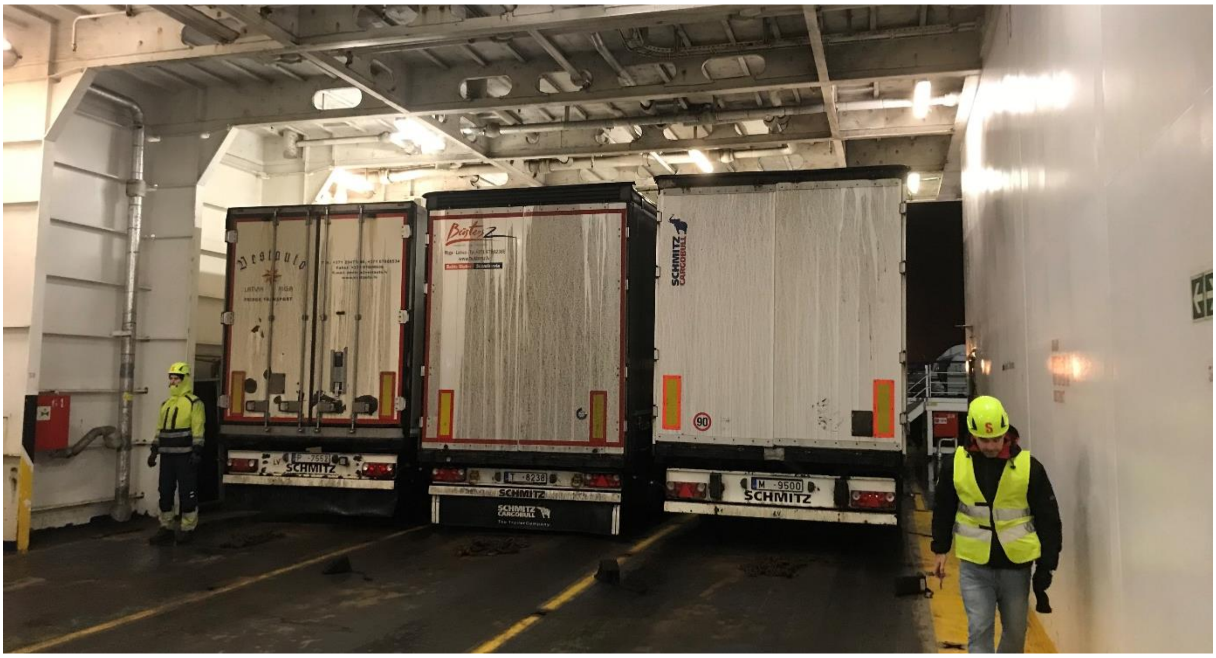


Figure 44. Typical cargo stowage on ro-pax and ro-ro ships (1)

Figure 45. Typical cargo stowage on ro-pax and ro-ro ships (2)

Figure 46. Typical cargo stowage on ro-pax and ro-ro ships (3)

Figure 47. Typical cargo stowage on ro-pax and ro-ro ships (4)

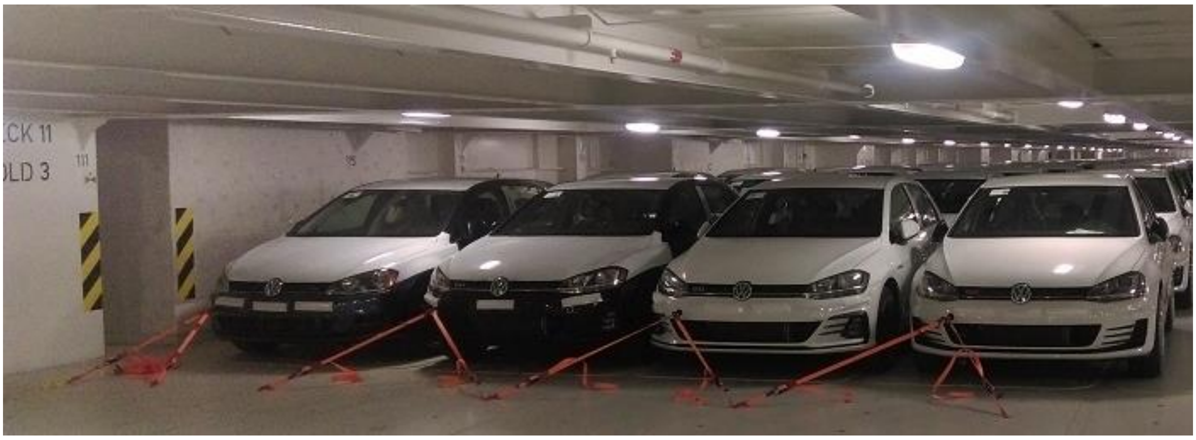


Figure 48. Example of loading on a vehicle carrier

Figure 49. Example of loading on a vehicle carrier below a hoistable deck

20.3 Design and production aspects

20.3.1 Vehicle space deck structure arrangement

The most common structural arrangement within the vehicle spaces on ro-pax and ro-ro cargo ships includes a grillage consisting of long span transverse girders (side to side) and longitudinal girders, with no pillars. This leads to web heights of primary supporting structure (longitudinal and transversal beams) in the range 600 mm-1200 mm where beams are extending from side to side. Typical spacing of transversal beams can vary from abt. 2200 mm-3600 mm. Spacing of longitudinal beams can vary from abt. 3000 mm-10 000 mm. Openings on girder webs can be arranged for the passage of equipment (piping, cables, ducts) and for weight reduction.

Arrangement of movable (hoistable) car decks is very common on ro-pax ships, usually within one vehicle space above the bulkhead deck. Structural height of movable decks can vary from 300 mm-400 mm. Similar arrangement can be also found on ro-ro cargo ships and vehicle carriers, sometimes with more levels (two or three) of hoistable decks in the same space. Hoistable decks may or may not be equipped with open lashing holes.

For Stena Flavia (generic ro-pax ship) and Magnolia Seaways (generic ro-ro cargo ship) the structural arrangement is illustrated in Figure 50, Figure 51 and relevant dimensions listed in Table 38, Table 39.

The most common structural arrangement within the vehicle spaces on vehicle carriers includes a grillage of transverse girders and longitudinal girders with one or two rows of pillars. The height of primary supporting structure (longitudinal and transversal beams) in the range 300 mm-500 mm. Typical spacing of transversal beams can vary from abt. 2200 mm-4200 mm. Spacing of the longitudinal beams is usually in line with pillar spacing, and can vary from abt. 6000 mm-15 000 mm. For typical structural heights please refer to Chapter 18. The structural arrangement of the generic vehicle carrier Torrens is illustrated in Figure 56.

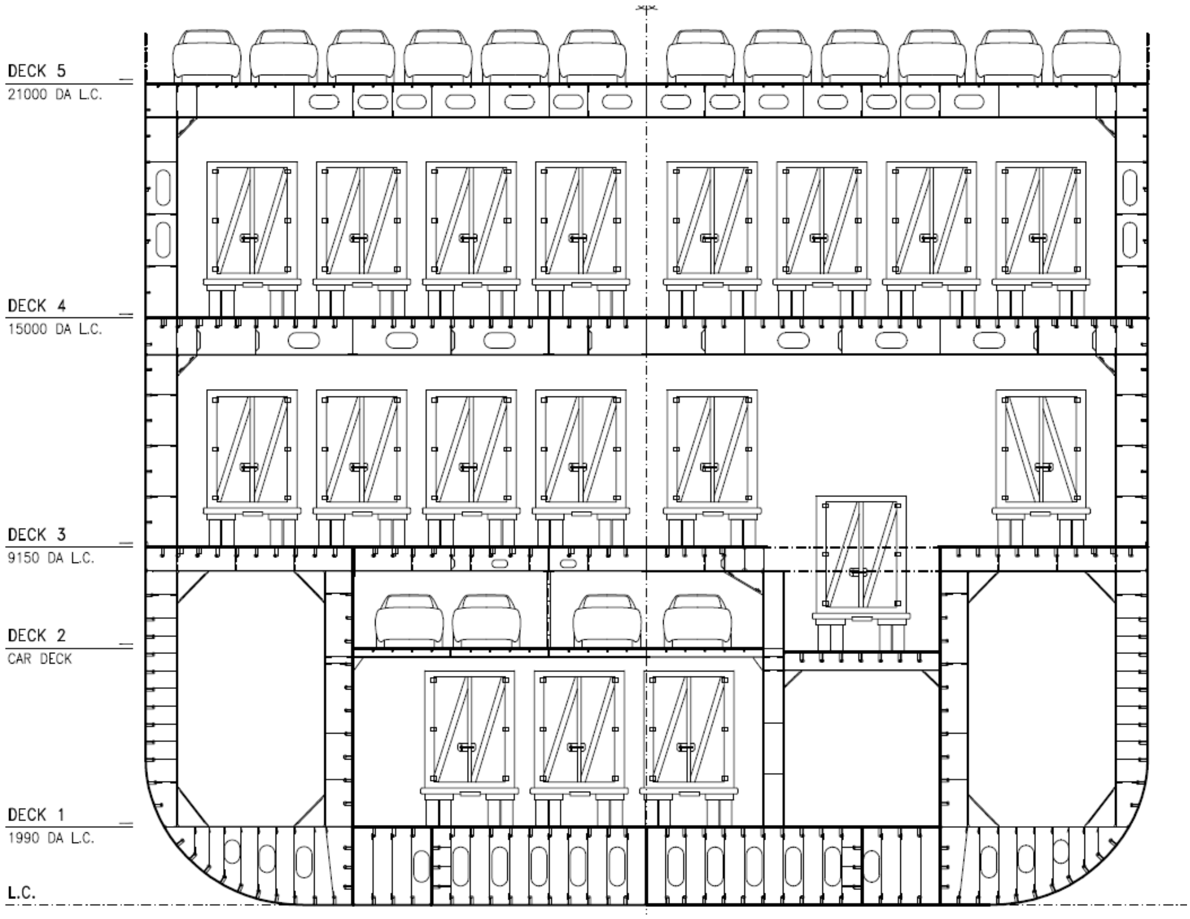


Figure 50. Stena Flavia ro-pax - Midship section

Table 38. Structural heights at Stena Flavia

Deck	Primary structure height, mm	Openings in primary structure, mm	Stiffeners height, mm
2	230	/	80
3	625	400x200	220
4	950	800x400	220
5	875	600x350, 750x350	80

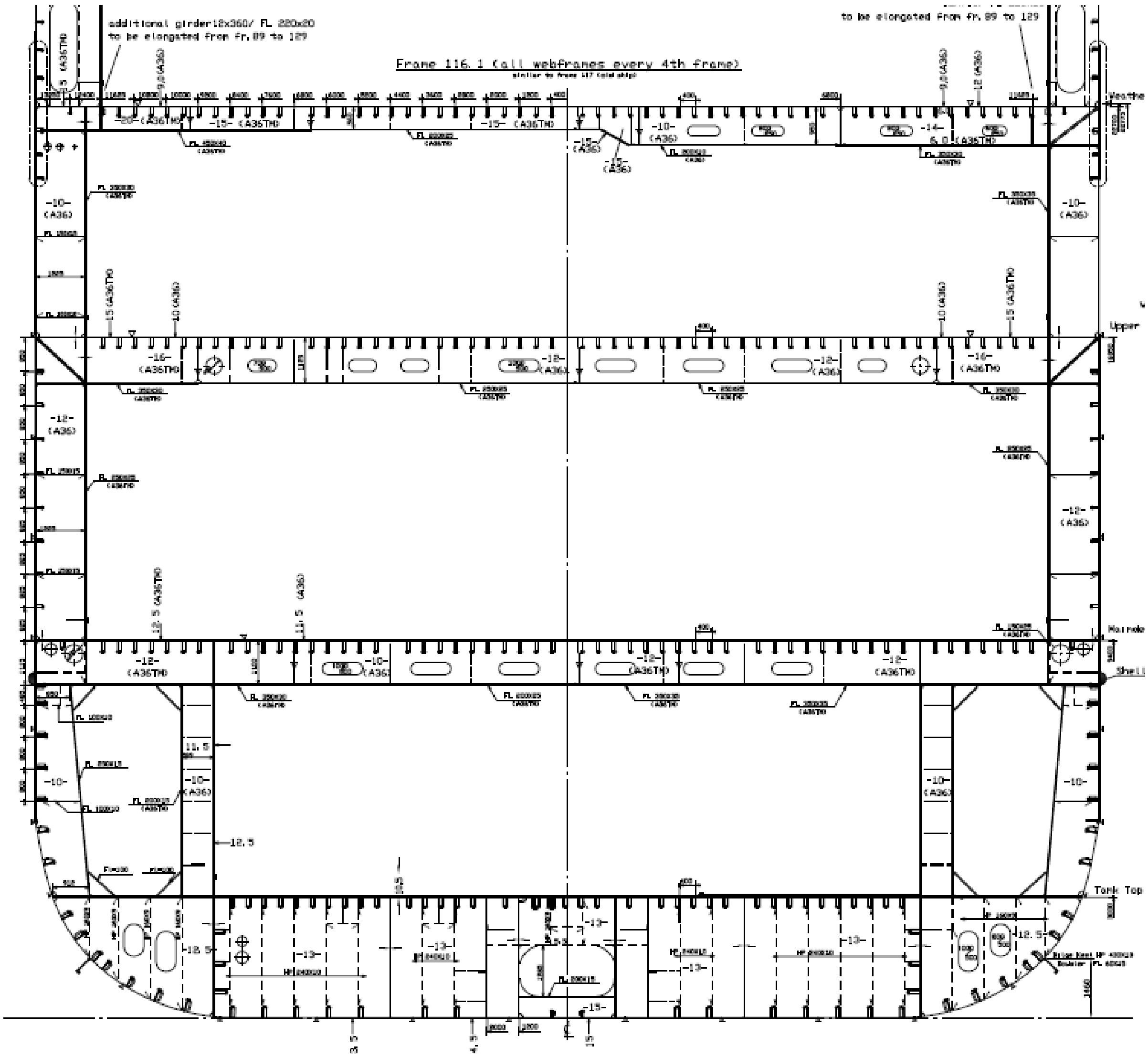


Figure 51. Magnolia Seaways ro-ro cargo - Midship section

Table 39. Structural heights at Magnolia seaways

Deck	Primary structure height, mm	Openings in primary structure, mm	Stiffeners height, mm
Main Deck	1130	1000x300	280
Upper deck	1150	1000x300	240
Weather deck	980	800x250	240

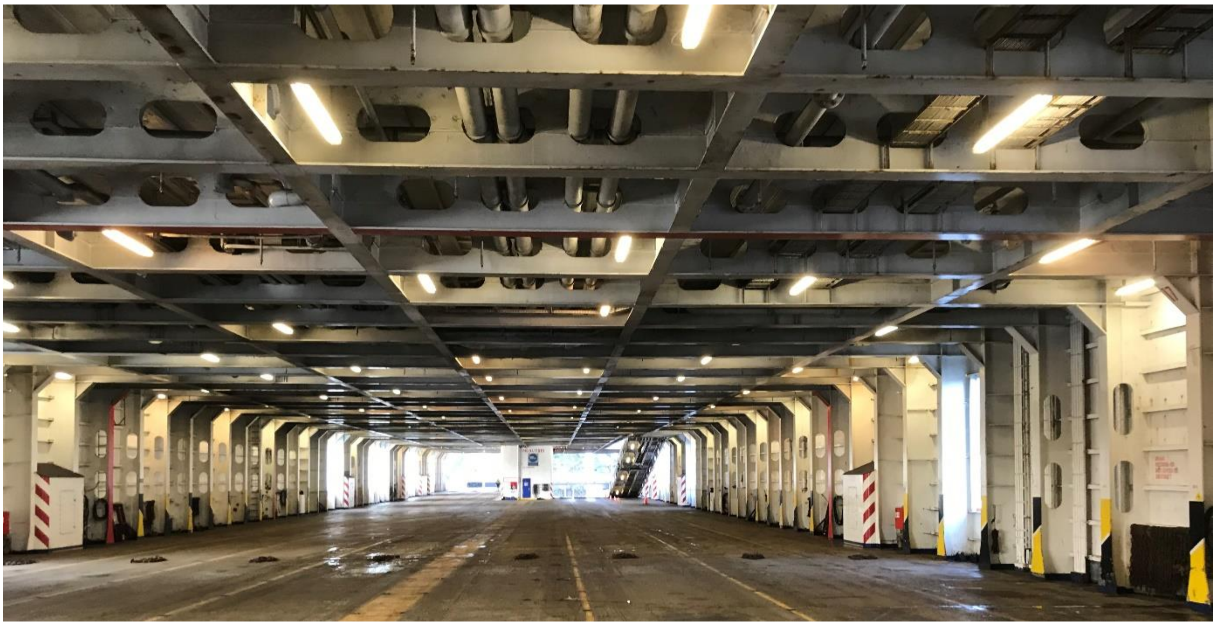


Figure 52. Typical vehicle space on a ro-pax ship (photo from Stena Flavia)

Figure 53. Typical vehicle space deck structure arrangement with insulation

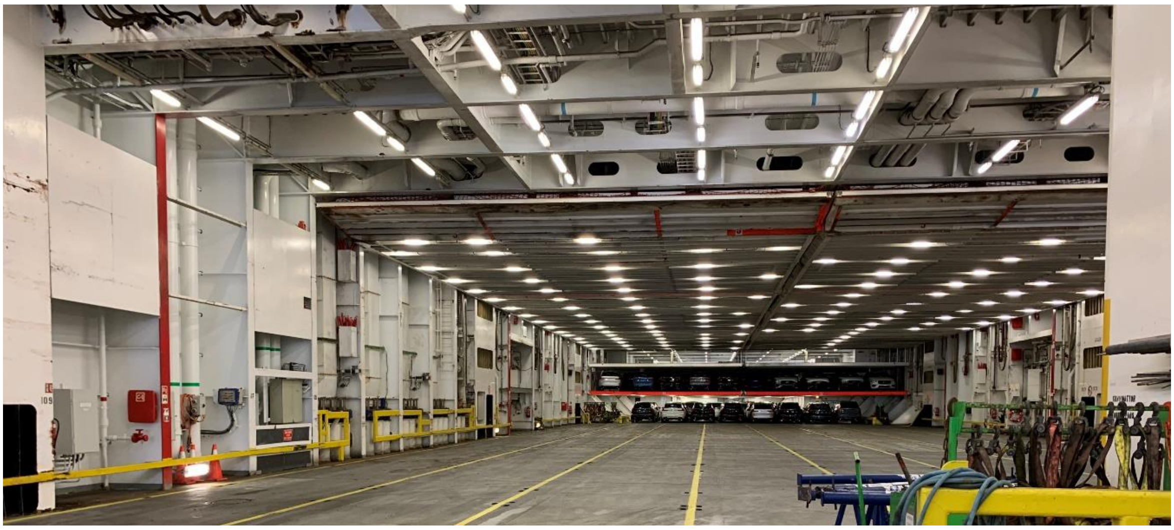


Figure 54. Typical vehicle space on a ro-ro cargo ship

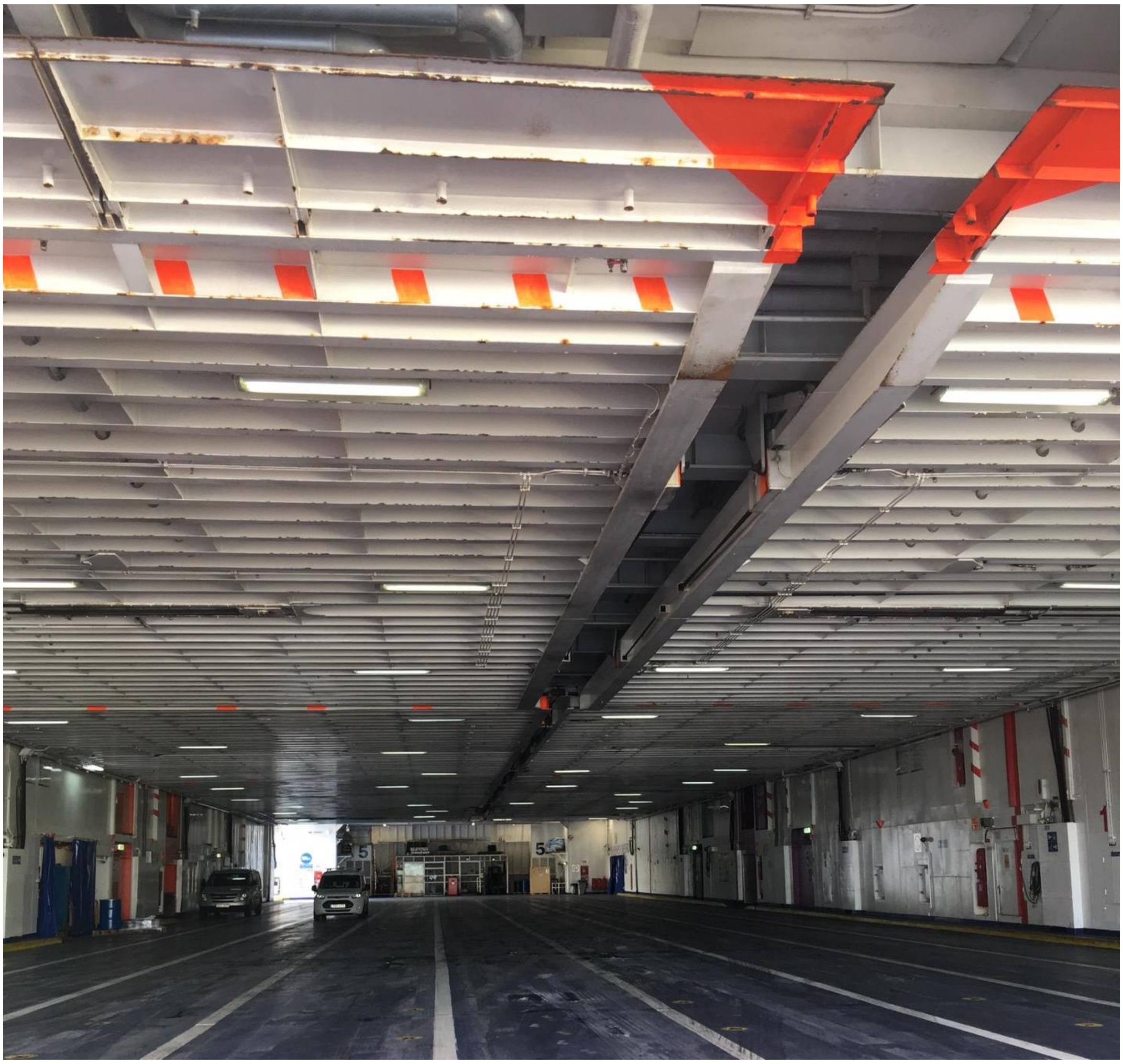


Figure 55. Typical vehicle space on a ro-pax and ro-ro cargo ship with movable deck arranged

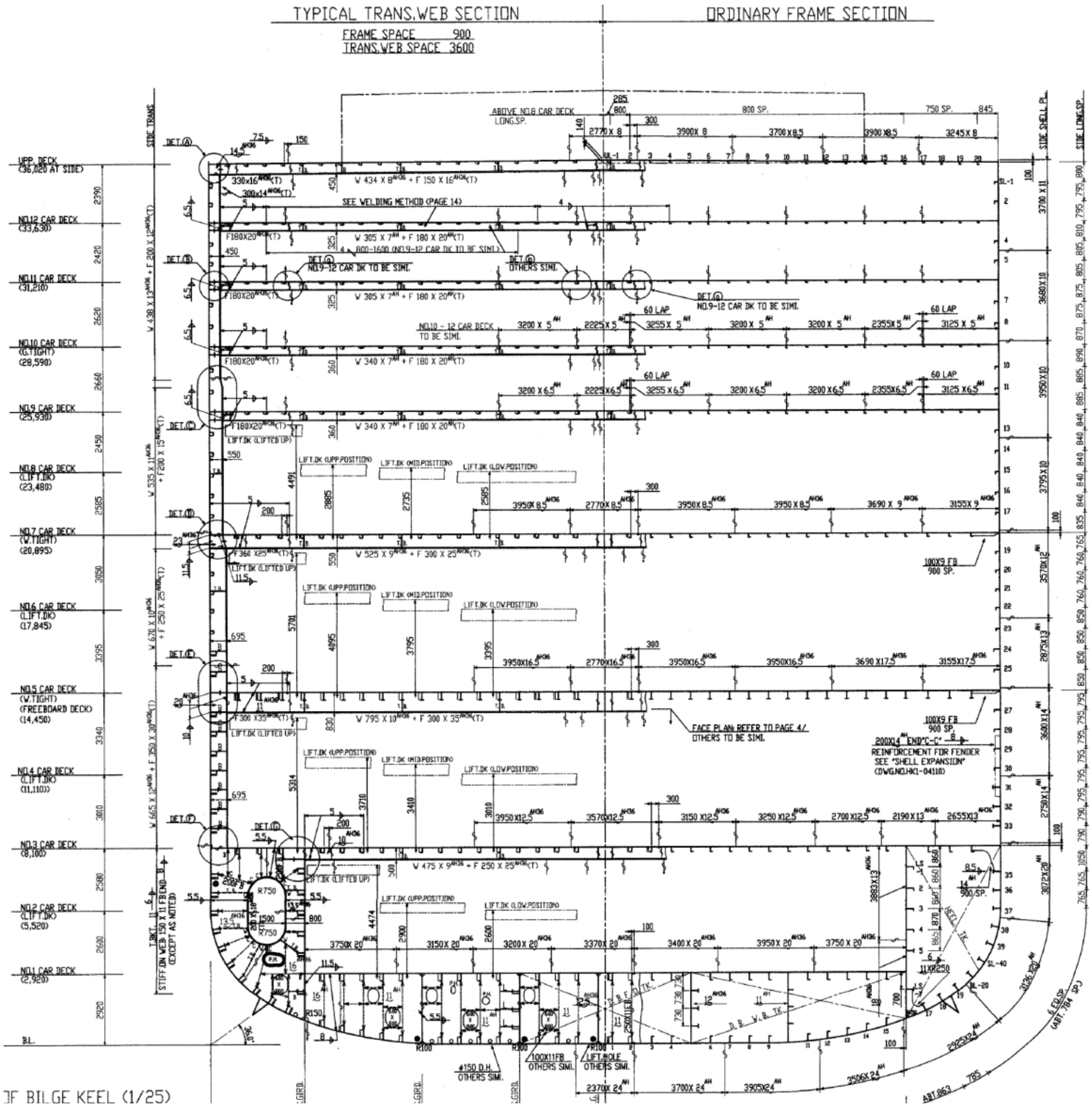


Figure 56. Torrens - Midship section

20.3.2 Vehicle space equipment arrangement

Typical equipment that can be found within a vehicle space includes the lightning system, cabling and piping of ship systems and the fire-fighting system that is usually arranged within the ship structure to avoid obstructions of the space available for cargo. In vehicle spaces arranged with hoistable or movable decks, specific equipment is additionally arranged such as electro-hydraulic jigger winches with flexible piping connections or deck lifters.

20.3.3 Materials

Typical structural material used on ro-ro ships[28] for ro-ro decks structural application is steel. Further, aluminum alloys can be used as well as alternative materials such as plywood and composite materials.

For description of alternative materials (composite, plywood, etc.), as well as standard materials used within a vehicle space (coatings, insulation, antiskid, etc.) see LASH FIRE internal report IR05.44.

20.4 Environmental aspects

Environmental aspects can be considered against the extinguishing media type, quantity of the released media etc. mixed with fire by-products that could be released into the environment. The medium used to extinguish fire should not be harmful to human or marine life to the extent similar to the requirement for other parts of the ship.

20.5 Proposals for development and restrictions

Fire test standards to be developed shall also consider alternative structural arrangement such as use of composite materials for ro-ro deck application.

Investigate or at least consider the impact of activation time to the performance of suppression system. As starting point, the realistic activation time considering detection, confirmation and decision making should be applied. Further, impact of a temporary stopping of the drencher system to allow crew entering the space shall be considered.

[28] fleet parameters considered at LASH FIRE, Ref Deliverable D05.1

21 Division of ro-ro spaces - Action 11-A

Main author of the chapter: Obrad Kuzmanovic, FLOW

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 11-A i.e. Division of ro-ro spaces.

21.1 Short Description of the addressed Action

The goal of the Action 11-A is to develop and demonstrate artificial and alternative means for fire integrity sub-division of ro-ro spaces, considering technologies such as water walls, fire resistant textiles, metal curtains etc. throughout the following tasks:

- Definition of conditions for division and sub-division of ro-ro spaces
- Investigation of requirement for horizontal division of ro-ro spaces
- Development of means for sub-division of ro-ro spaces
- Large scale validation of sub-division solutions

21.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

This section provides an overview of the requirements currently applicable to ro-ro spaces as per the existing rules and regulations and that may be related to the purpose of Action 11-A, i.e. ”Develop and demonstrate artificial and new means for fire integrity sub-division of ro-ro spaces”. Basically, this section summarizes the current requirements aimed at ensuring the fire integrity of ro-ro spaces.

21.2.1 General

21.2.1.1 Scope

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 11-A, i.e. ”Develop and demonstrate artificial and new means for fire integrity sub-division of ro-ro spaces”.s”.

21.2.1.2 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

A brief summary of the main regulation changes related to Division of ro-ro spaces is provided in Table 40 with a particular focus on regulations relevant to Action 11-A.

Table 40. Summary of regulation changes

Regulation change	Application date	Adoption date	Summary
SOLAS 74	1980[29]	1974	Introduces the principle of horizontal fire zone for ro-ro spaces / special category spaces with: • Structural fire protection • Fixed fire extinguishing system ("drencher" type) • Fixed fire detection system
MSC.338(91)	01/07/2014	30/11/2012	Raises the fire integrity requirements for ro-ro and vehicle spaces onboard cargo and passenger ships carrying not more than 36 passenger

The review is mainly based on the documents listed in Table 41.

Table 41. List of documents used for the review of regulations for Action 11-A

IMO Documents	SOLAS Convention, as amended
	2010 FTP Code, as amended
	MSC.1/Circ.1120, Unified Interpretations of SOLAS Chapter II-2, The FSS Code, The FTP Code and related Fire Test Procedures
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
	DNVGL Rules for the Classification of Ships, January 2017
	LR Rules and Regulations for the Classification of Ships, July 2016
Flag Administration Rules	MMF (French Flag Administration) Division 221 "Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage", 28/12/17 edition
	US Coast Guard Code of Federal Regulations (CFR) 46, 2019 online edition
	Swedish Transport Agency "Comments and interpretations by the Swedish Transport Agency regarding IMO Conventions", version 03 dd.15/05/2017
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

21.2.2 Requirements

21.2.2.1 General

This section describes the general requirements related to Division of ro-ro spaces and provides the associated reference(s) in the regulatory texts.

[29] It is to be noted that the concept of horizontal fire zone and associated safety measures has actually been introduced in SOLAS 60 part H as per IMO resolution A.122(V) dated October 1967. However, the circular was never made mandatory and Part H was therefore only applied on a voluntary basis until SOLAS 74 came into force. Compliance with Part H is formally recognized to be equivalent with SOLAS 74.

SOLAS II-2/9 details a very comprehensive set of measures for the purpose of containing a fire onboard a ship. The approach relies on a categorisation of each space, taking into account as a background both the fire risk in the space and the criticality of losing it. Basically:

- Some spaces are identified as key elements to ensure either proper fire-fighting or evacuation. Those are basically the control stations and the escape routes. Those spaces are to be preserved as much as possible from any fire.
- Other spaces are regarded as potential fire risks (with various risk levels) and the aim is to prevent a fire from spreading from and to those spaces.

Then SOLAS includes specific fire containment requirements including summary tables detailing the required level of fire integrity between spaces for the following ship categories:

- Passenger ships carrying more than 36 passengers;
- Passenger ships carrying not more than 36 passengers;
- Cargo ships other than tankers; and
- Tankers.

[SOLAS II-2/9]

Ro-ro spaces can be found on the first three types of ships. The corresponding fire containment requirements are detailed below.

21.2.2.2 Horizontal fire zones on passenger ships

[SOLAS II-2/2.2]

In principle, passenger ships are separated into main vertical zones, the length of which is normally limited to 40 m[30]. In order to accommodate garage spaces spanning potentially over the whole length of the ship, SOLAS II-2/20.2.2 allows the definition of horizontal zones which ”*may include special category spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m*[31]”. The required integrity for horizontal fire zones is the same as for main fire zones i.e.:

- A-60 fire integrity on passenger ships carrying more than 36 passengers, which may be reduced to A-0 where the space on the other side of the fire division has a very low fire risk (open decks, sanitary spaces or tanks, voids and machinery spaces with little or no fire risk)
- A class fire integrity on passenger ships carrying not more than 36 passengers, with detailed ratings in line with Table 42.

”Main vertical zone boundary integrity” also refers to complementary requirements, especially regarding the doors leading to the ro-ro vehicle spaces including, for practical purposes, that:

- Those doors are to be self-closing
- An indication that they are properly closed is to be available in the continuously manned central control station
- Arrangements are to be made to ensure local control of the doors, including power-operated doors, also taking into account the case of a fire (door to be operable up to 200°C)

---

[30] The length and width of main vertical zones may be extended to a maximum of 48 m (MVZ bulkheads to coincide with watertight bulkheads) or total area of MVZ must not be greater than 1600 m2 on any deck (to accommodate large public spaces, for instance)

[31] The way to measure this 10m height is further clarified in IMO MSC.1/Circ.1120 and IACS UI SC158.

[SOLAS II-2/9.4.1.1.5]

It should also be noted that the concept of the horizontal fire zone is also associated with an efficient fire-extinguishing system.

21.2.2.3 Fire integrity requirements for the boundaries of ro-ro and vehicle spaces

On passenger ships carrying more than 36 passengers, the boundaries–decks and bulkheads–of ro-ro and special category spaces are required to have A-60 fire integrity. This fire integrity level may however be reduced to A-0 where the space on the other side of the fire division has a very low fire risk (open decks, sanitary spaces or tanks, voids and machinery spaces with little or no fire risk).

[SOLAS II-2/20.5]

The fire integrity level required between ro-ro or vehicle spaces and other space on cargo ships or passenger ships carrying not more than 36 passengers is summarized in Table 42 below.

[SOLAS II-2/9 Tables 9.3, 9.4, 9.5 and 9.6]

Table 42. Fire integrity requirements around ro-ro or vehicle spaces

	Space categories	**Fire integrity requirement with respect to a ro-ro or vehicle space**
Key spaces to be preserved	Control stations	A-60
	Stairways and corridors	A-30
Potential fire risks	Category A machinery spaces	A-60
	Accommodation spaces and high fire risk service spaces	A-30
	Low risk service spaces, machinery spaces other than category A machinery spaces, open decks	A-0
	Cargo spaces (other than ro-ro and vehicle spaces)	A-0
	Other ro-ro or vehicle spaces	A-30

For practical purposes, there is no fire integrity requirement around a weather deck intended to carry vehicles, only a steel bulkhead or deck is required between such an area and another enclosed space.

The Swedish Flag nevertheless clarifies that, on cargo ships, weather decks intended to carry vehicles are to be considered as cat (11) same as enclosed ro-ro or vehicle spaces, and therefore similarly insulated with respect to other spaces.

[Comments and interpretations by the Swedish Transport Agency regarding IMO Conventions, interpretation of SOLAS II-2/9.2.3.3.2.2 (11)]

It is to be noted that the fire integrity requirements for ro-ro and vehicle spaces have been reinforced by MSC.338(91) amending SOLAS requirements for ships constructed after 01/07/2014. Prior to this date:

- There was no firm fire integrity requirement between two ro-ro or vehicle spaces, only this footnote "*Bulkheads and decks separating ro-ro spaces shall be capable of being closed* *reasonably gastight and such divisions shall have "A" class integrity in so far as reasonable and practicable, if in the opinion of the Administration it has little or no fire risk."*

- There was no fire integrity requirement between an open deck and a ro-ro or vehicle space, a mere steel bulkhead or deck was acceptable

21.2.2.4 Fire integrity

Fire integrity as per SOLAS corresponds to fire testing standards defined in IMO FTP Code. Dedicated fire test procedures are available for:

- Decks and bulkheads
- Pipe, duct and electrical cable penetrations
- Doors and windows
- Fire dampers

A-60 is the highest fire resistance rating defined in SOLAS. It corresponds to a 60 minute long fire test with 945°C maximum fire temperature.

SOLAS II-2/3 provides the following definition:

"A" class divisions" are those divisions formed by bulkheads and decks which comply with the following criteria:

.1 they are constructed of steel or other equivalent material;

.2 they are suitably stiffened;

.3 they are insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

class "A-60"	*60 min*
class "A-30"	*30 min*
class "A-15"	*15 min*
class "A-0"	*0 min*

.4 they are constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test; and

.5 the Administration has required a test of a prototype bulkhead or deck in accordance with the Fire Test Procedures Code to ensure that it meets the above requirements for integrity and temperature rise.

[SOLAS II-2/3]

21.2.2.5 Ventilation

The above mentioned fire integrity requirements are complemented by ventilation requirements which ensure that:

- The ventilation systems serving ro-ro and vehicle spaces are fully independent from those serving other spaces

[SOLAS II-2/9.7.2.1]

- The ventilation ducts serving ro-ro and vehicle spaces are insulated to A-60 standard when passing through other spaces

[SOLAS II-2/9.7.2.2 and SOLAS II-2/20.31.4.2 as interpreted by MSC.1/Circ.1120]

- The ventilation ducts serving other spaces are insulated to A-60 standard when passing through ro-ro and vehicle spaces

[SOLAS II-2/9.7.2.3]

21.2.2.6 Openings

Open ro-ro spaces and vehicle spaces may have openings on the side shell–mainly to ensure natural ventilation–or at their ends, possibly leading to a weather deck also intended for the stowage of vehicles. SOLAS II-2/20 currently includes a rather general requirement, stating that ”*Permanent openings in the side plating, the ends or deckhead of the space shall be so situated that a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces.*”

[SOLAS II-2/20.31.5]

MSC.1/Circ.1615 proposes to go beyond this rather vague requirement and completely ban open ro-ro spaces on passenger ships. It is to be noted however that MSC.1/Circ.1615 is a mere guideline, therefore applicable only on a voluntary basis, and targets only passenger ships.

[MSC.1/Circ.1615 §4.2]

21.3 Operational, design & production and environmental aspects

21.3.1 Requirements and restrictions due to the rules and regulations

Section 21.2 provides an overview of the requirements currently applicable to ro-ro spaces as per the existing rules and regulations where this section an overview from operational and production point is given as some of the most important explanations of the regulations should be mentioned, due to the high importance on the design of the vessels.

The main vertical fire zoning (as required by SOLAS Ch. II-2, Pt. C, Regulation 9.2), may not be practicable in vehicle spaces of passenger ships and, therefore, equivalent protection must be obtained in such spaces on the basis on horizontal zone concept and by provision of an efficient fixed fire-extinguishing system. As this concept may extend to a substantial or entire length of the ship, introduction of fire-classed sub-divisions will prevent the longitudinal fire spread to the same extent.
Specific requirements related to the fire detection and extinguishing system, ventilation system, lifesaving appliances and other are addressed with respect to:

- Type of cargo space
- Type of ship (ro-ro cargo ship, ro-pax ship, vehicle carrier)
- Cargo space arrangement: adjacent spaces to the cargo space (Classification of space with respect to fire hazard)
- Construction of cargo space boundaries: structural fire protection
- Requirements for cargo spaces intended for the carriage of dangerous goods

Moreover, ro-ro spaces are defined by cargo requirements (type of cargo, cargo capacity, cargo stowing, clear height, etc.), stability requirements (longitudinal and vertical sub-division, loading conditions, etc.), Rules and regulations requirements (fire safety etc.).

With respect to the arrangement, ro-ro spaces can be divided as follows:

- **Open ro-ro space**
  Open ro-ro spaces are those ro-ro spaces which are either open at both ends or have an opening at one end, and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides.
- **Weather deck**
  Weather deck is a deck which is completely exposed to the weather from above and from at least two sides.
- **Closed ro- ro space**
  Closed ro-ro spaces are ro-ro spaces which are neither open ro-ro spaces nor weather decks.

Additionally, the separation of ro-ro spaces, according to SOLAS, Ch. II-2, Pt. G, Regulation 19 for Carriage of Dangerous Goods, shall be as follows.

3.10.1 Separation shall be provided between a closed ro-ro space and an adjacent open ro-ro space. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, such separation need not be provided if the ro-ro space is considered to be a closed cargo space over its entire length and fully complies with the relevant special Rules and Regulation requirements.

3.10.2 In ships having ro-ro spaces, a separation shall be provided between a closed ro-ro space and the adjacent weather deck. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, a separation need not be provided if the arrangements of the closed ro-ro spaces are in accordance with those required for the dangerous goods carried on adjacent weather decks.

The introduction of sub-divisions can help to satisfy these requirements and can prevent longitudinal fire spread and resulting loss of control of the fire.

Ro-ro and vehicle spaces not capable of being sealed and special category spaces shall be fitted with an approved fixed pressure water spraying system for manual operation which shall protect all parts of any deck and vehicle platform in such spaces. Such water spray systems shall have, among others, a sufficient number of drainage valves. When fixed pressure water-spraying systems are fitted, in view of the serious loss of stability which could arise due to large quantities of water accumulating on the deck or decks during the fire-fighting operations, the drainage system below bulkhead deck shall be sized to remove no less than 125% of the combined capacity of both fixed fire-fighting system and the required number of fire hose nozzles. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. Means shall be provided to prevent blockage of drainage arrangements.

This SOLAS requirements must be considered when designing new sub-division systems, especially in case of water curtains or walls.

21.3.2 Requirements and restrictions regarding operational and design aspects

Ro-ro spaces in ro-ro cargo and ro-pax ships are usually arranged all along the vessel, without longitudinal or transversal sub-division and with as less as possible obstructions, such as pillars, casings or other ship structures and equipment, as the lanes shall be as unbroken as possible. These design requirements regarding ro-ro space arrangement present a challenge regarding successful prevention and suppression of fire and the introduction of fire-class sub-divisions (water walls, fire curtains, etc.) can substantially reduce that fire spread threat.
Sub-division devices should not intrude into the clear height/width profile of the cargo space in order to not interfere with the loading capacity or maneuver of vehicles. The required free height for cargo can be a limiting factor for the type of closure devices that are feasible. Examples of typical arrangements in ro-ro spaces are illustrated in Figure 57 and Figure 58, where the equipment (piping, cables, etc.) are “incorporated” in the deck/side structure.

Figure 57. Typical ro-ro space (1)

Figure 58. Typical ro-ro space (2)

Design of the novel equipment must be done in coordination with the designs of all other equipment (hoistable car decks, movable ramp systems etc.) and systems piping and fittings in ship sides, casings or under deck, as seen in Figure 57 and Figure 58.

Stowage patterns should be considered in general but are especially important for restricted areas, such as in lower holds, close to ramps, fore/aft ends of decks and at partial weather decks.

Any division device fitted athwartships should be located along ship in such way to consider parking positions of trailers and trucks.

Curtains or similar innovative equipment to be applied when cargo is located in way of closure may be investigated.

Closing/opening operation should be such that cargo operations times are not prolonged. Solutions only to be engaged in case of fire may be evaluated.

Minimum fire division requirements A-0, A-30 etc. to be applied considering purpose of division. If division is only to prevent free flow of air/oxygen into for example an open aft closed ro-ro deck even solution not compliant with A-0 may be evaluated.

The results of the FIRESAFE II project must be also considered - the description of investigated solutions regarding fire integrity sub-divisions can be found in final report available on the Teams platform *LASHFIRE/General/Related Research*. In particular, annual costs associate with reduced cargo capacity will be very cost driving and therefore cargo separation should be avoided as far as practicable. Furthermore, personnel safety must be properly considered. For example, a side folded wall could technically be possible but may need to be disregarded for safety and operational reasons since it poses an intrusion in the side walk, which poses a collision hazard. Except personnel safety, it may also delay cargo operations, cause loss of cargo and delay cargo handling.

Impact on fire patrolling and manual firefighting, by restricting passage and view, must be considered. Passage doors may have to be arranged in closure devices.

The new sub-division systems must not be hazardous to the crew and passengers and to require additional means of escape beside the ones required. These systems should not have negative effect on ventilation requirements also and be simple from operational and maintenance aspects, if possible. In general, such systems should preferably not require any stricter regulation in comparison with the current rules.

CCTV, detection, manual equipment location, drencher zones must be coordinated.

Mitigation of risks with alternatively fueled vehicles (AFV), especially regarding e-vehicles, is also becoming very important topic. In particular, the means of separation of dedicated areas for localization and charging of such vehicles should be taken into consideration. The appropriate level of insulation of such spaces could also be assessed.

Finally, the novel system for fire sub-divisions must not use harmful materials and substances to the environment.

22 Ensuring safe evacuation – Action 11-B

Main author of the chapter: Obrad Kuzmanovic, FLOW

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 11-B i.e. Ensuring safe evacuation.

22.1 Short Description of the addressed Action

Safe return to port and safe evacuation must be ensured for 3 hours in case of a fire on a large passenger ship. However, the requirement only applies if the fire is contained within the first fire zone, but between fire zones and to escape routes integrity requirements only apply for 1 hour, which is crucial in fire.

The goal of the Action 11-B is to develop solutions and recommendations to ensure safe evacuation during safe return to port (fire integrity for 3 hours) and when arriving at foreign port, throughout the following tasks:

- Definition of conditions for evacuation
- Evaluation of fire integrity to ensure safe
- Ensured second means of walk-off abandonment

22.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

22.2.1 General

22.2.1.1 Scope

This section aims at giving an overview of the requirements applicable to ro-ro spaces regarding action 11-B, i.e. "Ensuring Safe Evacuation".

22.2.1.2 Applicable regulations

The present review is based on the currently applicable regulations and is mainly based on the documents listed inTable 43.

Table 43: List of documents used for the review of regulations for Safe evacuation and SRTP

IMO Documents	Safety of Life at Sea (SOLAS) Convention, as amended in 2017
	IMO Circular MSC.1/Circ.1505 "Unified interpretation of SOLAS regulation II-2/13.6"
	IMO Circular MSC.1/Circ.1369 "Interim explanatory notes for the assessment of passenger ship systems' capabilities after a fire or flooding casualty"
IACS & Class Rules	BV NR598 "Implementation of Safe Return to Port and Orderly Evacuation" dd. January 2016
Flag Administration Rules	N/A

22.2.2 Requirements

22.2.2.1 General

This section describes the general requirements related to Safe evacuation and SRtP and provides the associated reference(s) in the regulatory texts.

A number of precautions are taken in order to prevent a fire in the ro-ro spaces from jeopardizing escape from other spaces and ship evacuation.

As a general rule, vertical escape ways are categorized as “stairways” (category (2) on passenger ships carrying more than 36 passengers and category (4) on passenger ships carrying not more than 36 passengers), which ensures that they are suitably insulated with respect to ro-ro spaces.

In addition, on passenger ships carrying more than 36 passengers, a specific category (category (4)) is defined to cover “Evacuation stations and external escape routes”, so that A-60 insulation is required between ro-ro spaces and muster stations; lifeboat/liferaft stowage areas as well as their lowering paths.

22.2.2.2 Escape ways from ro-ro spaces

At least two means of escape leading to the embarkation deck are required from ro-ro spaces as per SOLAS II-2/13.6, one at the fore end of the space and one at the aft end.

[SOLAS II-2/13.6]

In ro-ro passenger ships, designated walkways at least 600mm wide are to be marked and kept clear throughout the ro-ro or vehicle spaces.

[SOLAS II-2/13.5.1]

22.2.2.3 Protection of escape ways from other spaces

SOLAS includes provisions that protect the means of escape from spaces below the ro-ro spaces from being cut off by a fire in the ro-ro spaces:

- Accommodation spaces, service spaces and control stations are to be provided with two means of escape, one of which is to be an enclosed stairway providing continuous fire shelter up to the embarkation deck. Access from the stairway to the embarkation areas is to be insulated as a stairway, as per SOLAS II-2/13.3.2 and SOLAS II-2/13.3.3; and
- Machinery spaces are to be provided with two means of escape, as per SOLAS II-2/13.4. In addition, SOLAS II-2/13.5.2 makes it clear that, for machinery spaces where crew is normally employed, one of the escape routes is not to pass through ro-ro spaces.

In addition, SOLAS II-2/13.7 includes a number of provisions aiming at making the escape routes on ro-ro passenger ships as easy and direct as possible, with a view to quicken evacuation if needed, especially:

- Minimum number of changes in direction along a route;
- There should be no need to cross from one side of the ship to the other during escape;
- Passengers should not need to climb more than 2 decks up or down to reach an assembly station; and
- External escape routes are required from open decks.

22.2.2.4 SRtP regulations

The SRtP regulations are found in SOLAS II-2/21 and 22. They apply only to large passenger ships - including ro-ro passenger ships, with length greater than 120 m or with more than 3 MVZ - and aim at ensuring that:

- After a limited fire or flooding casualty, the ship will be able to bring the passengers and crew back to a port without need for evacuation of the ship: This is referred to as “Safe Return to Port”; or

- After a larger fire or flooding casualty, key systems will remain available for 3 hours to support ship evacuation: This is referred to as “Orderly evacuation”.

For practical purposes, it is worth noting that:

- The SRtP regulations do not consider the fire-fighting step, they are focused on ship operational capacities after a casualty, the extent of which is defined; and
- The SRtP regulations do not care about ship structure or stability, they are only focused on systems design.

22.2.2.4.1 SRtP – Safe Return to Port

The Safe Return to Port regulations are specified in a very goal-based way in SOLAS II-2/21, requiring that a number of safety systems remain operational after a pre-defined fire or flooding casualty – based on the idea that the ship itself is safer than a lifeboat to bring people back to a port. For practical purposes, this requires a higher level of redundancy for those systems since they need to remain fully operational after losing the components located in any one group of spaces which can be affected by a fire or flooding casualty. Where redundancy is not practicable, some key components may also be protected by fire insulation, reinforced pipe thickness etc.

A flooding casualty is defined as the flooding of any single watertight compartment.

[SOLAS II-1/8-1.2]

The fire casualty threshold is defined as – see also the figures below for illustration:

- Any group of spaces enclosed by A-class boundaries if the space where fire is supposed to have originated is protected by a fixed fire-extinguishing system; or
- Any group of spaces enclosed by A-class boundaries and adjacent spaces up to the nearest "A" class boundaries otherwise.

[SOLAS II-2/21.3]

Figure 1 : Casualty threshold when the space of fire origin is protected by a fixed fire-extinguishing system - Longitudinal section

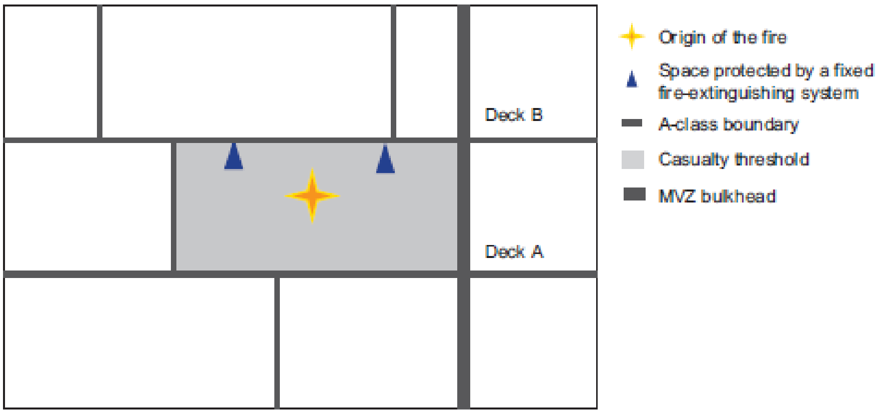
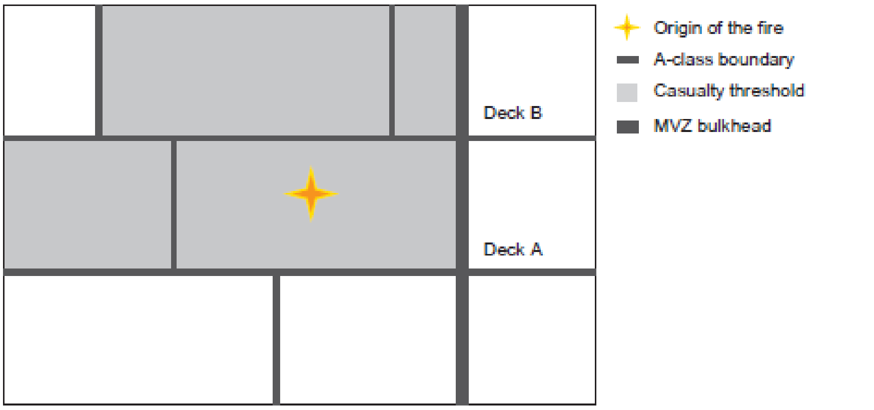


Figure 2 : Casualty threshold when the space of fire origin is not protected by a fixed fire-extinguishing system - Longitudinal section



It is to be noted that the above definition would lead to considering total loss of any garage space as a fire casualty to be considered. For practical purposes however, it is allowed to consider that the fire casualties in the garage spaces do not extend further than two adjacent drencher sections.

[BV NR598 [1.2.1.c]]

The concerned systems are listed below – The systems shown in bold actually serve ro-ro spaces and may be involved in fighting a fire in a ro-ro space:

- propulsion;
- steering systems and steering-control systems;
- navigational systems;
- systems for fill, transfer and service of fuel oil;
- internal communication between the bridge, engineering spaces, safety centre, fire-fighting and damage-control teams, and as required for passenger and crew notification and mustering;
- external communication;
- fire main system;
- fixed fire-extinguishing systems;
- fire and smoke detection system;
- bilge and ballast system;
- power-operated watertight and semi-watertight doors;

- systems intended to support "safe areas", i.e. sanitation, ventilation etc. with a view to bringing the passengers back home with a minimum level of comfort; and
- flooding detection systems.

[SOLAS II-2/21.4]

For practical purposes, BV Class Rules clarify that after a fire casualty affecting a ro-ro or vehicle space, the fire main should still be able to cover the vehicle space (possibly using hydrants outside of this space).

[BV NR598 [1.2.1.c]]

22.2.2.4.2 Orderly evacuation

In case a casualty happens that has a greater extent than the theoretical casualties defined for SRtP, it is reckoned that the ship will have to be evacuated and SOLAS II-2/22 requires that the following systems remain serviceable for at least 3 hours in the remaining MVZ in case of a fire casualty in any one MVZ or horizontal zone, with a view to ensure smooth evacuation of the ship:

- Fire main;
- Internal and external communication systems;
- Bilge systems;
- Lighting along escape routes, at assembly stations and at LSA embarkation stations; and
- Guidance systems for evacuation.

SOLAS II-2/22 requires 3 hours operation for the systems supporting ship evacuation. This duration is a performance requirement for the systems but does not imply that the fire casualty triggering the evacuation of the ship is expected to last 3 hours - indeed, it is to be noted that cabling and piping enclosed in a trunk insulated to A-60 standard may be considered still serviceable even if they pass through the affected MVZ.

The underlying scenario is rather that a fire casualty has occurred and its extent or consequences exceed the level that makes SRtP feasible. In this case, the master is expected to decide ship evacuation and the purpose of the regulation is to ensure that, even with any one MVZ lost, the key systems for evacuation will remain functional. The “orderly evacuation” regulation does not consider how or whether the fire casualty is fought.

22.3 Operational aspects

Operational aspect regarding new walk-off means: Easy and fast to deploy or install and use, maintenance friendly, should be flexible enough to compensate the height/length difference and/or ship motions due to waves.

It is recommended to review some recent cases where a vessel suffering from fire event is moored at normal (with shore-based gangways etc) or temporary quay (with no gangways, only debarkation at low level possible). If fire or smoke is on main deck, that later case may be very challenging (in case of Stena Spirit below passengers were relocated due to smoke present on muster station). Considerations must be made to smoke spread to non-fire affected areas and accommodation.
For sample information on real cases see references [24] and [25].

LSA equipment, muster stations and passageways between need to be protected from flames, heat, smoke and structural damages.

Fire scenario analysis has to be performed for different scenarios of fires and evacuation methods, to determine best and quickest solution for each fire and evacuation case. A realistic evacuation scenario has to be predicted for all fire scenarios.

22.4 Design and production aspects

Safe Return to Port (SRtP) and Orderly Evacuation requirements are mandatory for all passenger ships constructed after 1 July 2010 having length of 120 m or more or having three or more Main Vertical Zones (MVZ).

The SRtP requirements are covered with SOLAS, Chapter II-2, Part G, Regulations 21, 22 and 23, where definition of Casualty Threshold has been described. In case that casualty threshold is not exceeded, ship must be capable to return to port under its own power (after one fire or one-compartment flooding) and all essential systems shall remain operational during safe return to port. Orderly evacuation can be carried out when Casualty Threshold has been exceeded and necessary systems must remain operational for 3 hours to support evacuation & abandonment of the ship. However, the decision on whether or not to evacuate the ship remains with the Master.

The above mentioned requirements only apply if the fire casualties are contained within one MVZ, but between fire zones and to escape routes integrity requirements only apply for one hour, which is crucial in fire. Therefore, an assessment of fire integrity requirements between MVZ (A-60) and towards escape routes shall be performed in relation to the present Safe Return to Port requirements (to remain operational for supporting the orderly evacuation for three hours). The study has to include identification of weak areas of fire integrity, evacuation and heat transfer simulations in order to determine real fire integrity requirements.

The arrival at foreign port after safe return to port and safe evacuation is also a topic not very well covered by present SRtP regulations, especially for Ferries and Ro-Pax vessels (the scenario when the fire blocks ro-ro and passenger loading ramps and gangways also cannot be used due to foreign port). Therefore, an investigation of second walk-off options will be performed, together with evacuation simulations and assessment of emergency operation procedures (walk-off abandonment in given time) related to the present SRtP requirements.

The cost assessment will be calculated for both solutions.

Design and production aspects regarding fire integrity material: as light weight and thin as possible, implementation of new material to be coordinated with design and arrangements of all other systems, should not produce toxic fumes when burning.
Design and production aspects regarding new walk-off means: light weight, should not require too much space when stowed.

22.5 Proposal for development and restrictions

It is necessary that the design of secondary means of escape will be customized for the single ship due to different ship arrangement as well as different port, terminal or quay arrangement in operational area. Nevertheless, the operational system or principle of such means should be standardized or at least similar enough in order to decrease the risk of human errors in emergency situations.

Use of MES to quay side (similar as in airplanes today) should be considered also, as the time needed for evacuation thus can be significantly decreased.

23 Safe design with ro-ro space openings - Action 11-C

Main author of the chapter: Martin Carlsson, STL

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 11-C i.e. Safe design with ro-ro space openings

23.1 Short Description of the addressed Action

Action 11-C objective is to develop ro-ro space openings design guidelines by assessment of the risks of smoke and heat transfer from ro-ro space openings to life-saving appliances, adjacent areas and ventilation inlets through:

- Definition of conditions for ro-ro space openings
- Establishment of safe design with ro-ro space openings
- Fire tests and large scale validation of safe design with ro-ro space openings

23.2 Regulation Review

Main author of the chapter: Blandine Vicard, BV

23.2.1 General

23.2.1.1 Scope

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 11-C i.e. “safe design with ro-ro space openings”.

23.2.1.2 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

Table 44: List of documents used for the review of regulations for Action 11-C

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue book dated January 2019
	BV Rules for Steel Ships (NR467), as amended in July 2019
	DNVGL Rules for the Classification of Ships, December 2019
	LR Rules and Regulations for the Classification of Ships, July 2019
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 28/12/17 edition

23.2.2 Requirements

23.2.2.1 General

This section describes the general requirements related to Action 11-C with respect to fire safety, and provides the associated reference(s) in the regulatory texts.

As outlined in §**Error! Reference source not found.**, the general SOLAS [5] principle for ro-ro or vehicle spaces is that they may be either:

- Weather deck i.e. fully opened to the weather, especially there should be no deck above; or
- Enclosed spaces; or
- "Open" ro-ro or vehicle spaces, i.e. a number of permanent openings on the sides and at the ends of those spaces are allowed, especially for ventilation purposes. The present reports focuses on such openings, since it is understood that experience on past ro-ro fires has revealed that, in the case of a fire in the open ro-ro or vehicle space:
    - They prevent effective shutting down and control of ventilation for fire extinguishing purposes i.e. the openings provide unlimited oxygen supply, allowing the fire to spread uncontrollably, and
    - They may boost fire propagation to other areas, adjacent or above the concerned open ro-ro or vehicle space, and possibly jeopardize life-saving appliances carried on board.

23.2.2.2 Protection of other spaces and of survival craft

23.2.2.2.1 General principle

In general, survival craft stowage areas and embarkation stations are assigned a specific category for the purpose of applying SOLAS II-2/9 regulation [5], as well as other enclosed spaces. Ro-ro or vehicle spaces are required to offer a certain fire integrity with respect to such spaces, meaning that ro-ro or vehicle spaces openings cannot be immediately adjacent to survival craft stowage areas or embarkation stations, accommodation spaces, service spaces and control stations. The openings could however be located right below such spaces or areas.

23.2.2.2.2 Survival craft

SOLAS III/15.1 [5] forbids any opening below embarkation stations for MES (Marine Evacuation Systems, i.e. evacuation chutes).

[SOLAS III/15.1]

SOLAS III/13.1.2 [5] requires that "Each survival craft shall be stowed […] in such a position that the survival craft in the embarkation position is not less than 2 m above the waterline with the ship in the fully loaded condition under unfavourable conditions of trim of up to 10° and listed up to 20° either way, or to the angle at which the ship's weather deck edge becomes submerged, whichever is less."

[SOLAS III/13.1.2, SOLAS III/16]

Based on this requirement, together with the requirements of SOLAS III/16 [[5], it is usually required that the survival craft can be lowered along the hull without interfering with the ship structure or any protuberance on the side of the ship, considering 10° trim and 20° list. For practical purposes, this tends to forbid side openings in ro-ro spaces below survival craft launching areas.

23.2.2.2.3 Ro-ro and vehicle spaces permanent openings

As a general principle, SOLAS III/13.1.5 [5] requires that "Each survival craft shall be stowed as far as practicable, in a secure and sheltered position and protected from damage by fire and explosion." In addition and more widely, SOLAS II-2/20 [5] requires that permanent openings be so located that "a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces."

[SOLAS II-2/20.3.1.5]

As a side note, it can be outlined that, although this requirement is found under the headline "3 Precaution against ignition of flammable vapours in closed vehicle spaces, closed ro-ro spaces and special category spaces", it is usually also taken into account for open ro-ro and vehicle spaces as well.

It nevertheless remains very qualitative and therefore its application relies on the appreciation of the Flag Administration.

Chinese Flag Administration, in their domestic regulations, consider that 3 m distance between ro-ro space openings and survival craft stowage areas or embarkation stations is sufficient (IMO, 2018) [7].

Furthermore, EMSA, following the FIRESAFE II study [56], has been proposing minimum distances between permanent openings in the sides and ends of ro-ro spaces and survival craft, which resulted in IMO *Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger* ships, MSC.1/Circ.1615 [11], recommending at least 6 m measured horizontally between a cargo space side opening and survival craft, marine evacuation systems, embarkation stations and muster stations.

[MSC.1/Circ.1615 §5]

23.2.2.3 Ban of openings

One step further to the measures mentioned above consists in banning openings in ro-ro and vehicle spaces, as recommended by IMO *Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships*, MSC.1/Circ.1615 [11].

[MSC.1/Circ.1615 §4.2]

23.3 Operational aspects

23.3.1 Considerations on open ro-ro cargo space

Historically, deck volumes located transversely in way of side openings and in way of aft and forward openings could be excluded from the net tonnage. This is however not anymore allowed: all spaces intended for carriage of cargo should be included in net tonnage. Therefore, closure/banning of side openings will not affect net tonnage or port or fairway fees that are based on net tonnage.

According to the IMDG code, the Administration may allow carriage of certain dangerous cargo on open ro-ro cargo space, for example DG classes where main risk factor is emission of gases. Also, livestock may be carried and reefer units running on diesel.

If open ro-ro cargo space is not allowed, electric connection sockets with cables for reefers shall be installed, leading to additional components, installation and operation/maintenance cost, as well as added fire risks.

Open ro-ro cargo space is provided with natural ventilation, thereby mechanical ventilation system is not required, which reduces costs in terms of investment, power requirements, space claim and maintenance.

If openings would be closed, electrical power requirements would increase due to the ventilation system and reefer connection sockets requirements, with negative environmental impact due to increased fuel consumption and increased operational and investment cost.

Consequences on the cargo stowage and loading/unloading operations, which are caused with closure of end openings, must be investigated thoroughly, as may lead to loss of cargo capacity, available space for dangerous goods and increased time in port.

The value of a “small” weather deck aft of a closed ro-ro cargo space will be increased, if the open ro-ro cargo space will be prohibited, since dangerous goods capacity will be limited. Efficiency of such weather decks must be secured to preserve efficiency of vessels.

23.3.2 Shutters on side and aft/fwd openings

Shutters for side openings, to be deployed in a fire situation only, has no operational influence apart from the maintenance of the closing mechanisms. It should however be considered that the environment is very demanding with constant salt spray, ice/snow and wind. Function of the device must be very robust to work under all circumstances and to minimize the required maintenance. Manual local emergency operation for such application is not a good solution, since shutting must take place when fire/smoke is already a fact.

Closing devices for fwd/aft ends of the cargo space have impact on cargo operations since solution will influence movement and stowage of vehicles. For this application different solutions may be discussed:

a. No opening, permanent closure by structure
b. Opening, closure in seagoing condition
c. Opening, closure in fire situation only

23.3.3 Toxic gases, from electric battery car fires especially

All fires in vehicles and many of cargo fires will generate toxic gases. This is particularly the case for electric cars suffering from thermal runaway. Ventilation of such gases is essential for the wellbeing of crew, fire squad and passengers.

Ventilation may also cause problems depending on the gas flow. For example, leakage of toxic gases to public spaces through openings in the side of the vessel or through fire doors at the ro-ro cargo space.

Thermal runaway of a Li-ion battery is independent of oxygen supply, in the sense that the thermal event is not worsened by air flow/ventilation. Some investigations suggest parking of electric vehicles on open decks or weather decks with natural ventilation.

Gas emissions from gas driven vehicles must be considered.

23.3.4 Other openings

In the open ro-ro cargo space, there can be other openings arranged, not intended for natural ventilation, intended for ship systems/equipment as follows:

- Mooring
- Bunker boat mooring
- Accommodation ladder
- Pilot access
- Access to Man Over Board-boat
- Access to LSA equipment

- Bunkering operation

23.4 Design and production aspects

From the open ro-ro cargo space design and production point of view, the following shall be considered:

- satisfy the rules requirements so the cargo space can be considered “open ro-ro space”,
- maximize the openings to reduce weight,
- fulfilling the structural strength requirements at the area with openings,
- avoid interference of opening with other equipment and systems (ventilation, lifesaving equipment, stairways, engine casing and other, etc)
- Cargo requirements (clear height, type of cargo, etc.)
- Loading/unloading system for cargo (rampways, cargo doors, stowage etc.)

23.4.1 Open ro-ro cargo space configurations

There are several configurations of open ro-ro cargo space, to be considered:

- Openings on both forward and aft ends with superstructure above
- Small garage forward with openings on the aft end and sides, large weather deck aft
- Large garage forward with openings on aft end and sides, small weather deck aft
- Large garage forward with openings on aft end where no openings on sides, small weather deck aft (note: not fulfilling the SOLAS Chapter II-1 Reg 3.35 requirements for open ro-ro cargo space)
- Open ro-ro cargo space where mooring equipment/deck is arranged in the cargo space, covered poop deck or forecastle with open or closable mooring hatches, fairleads always open
- Two levels of open roro decks, mainly on ro-ro cargo vessels

Further, there are several arrangements with respect to the opening geometry at forward and aft ends of the open ro-ro cargo space, to be considered:

- Straight edge of deck above or alternative shapes
- Center or offset casing
- Clear height
- Cargo drive/parking patterns
- Unobstructed crew passage during operation such as fire patrol or in emergency

Several configurations from existing ships are illustrated in the ANNEX J2 Selected FIRESAFE I & II references and ANNEX J3 Aft weather deck and opening samples.

23.4.2 Side openings closure aspects

If closure of the openings shall be arranged, the following shall be considered:

- additional weight
- system requirements (ventilation, etc)

- Installation cost
- ro-ro cargo space type
- cargo restrictions (DG, loading/unloading operation, cargo capacity, etc)

Regarding the additional weight, permanent closing of side openings will lead to an increased weight due to added structure and system (mainly ventilation) requirements, thus, increasing the lightweight of ship i.e. reducing the available deadweight and payload. The main additional weight items include steel for openings' closure and additional ventilation ducts as well as additional ventilation system requirements (ventilators, cabling).

For example, closing side openings on the selected generic ship Stena Flavia would lead to an increased steel structural weight by abt. 27 tons and ventilation equipment weight of abt. 6 tons. This adds abt. 0.25% to lightweight and leads to 0,5% decrease of deadweight.

Generally, the weight increase is higher on an existing vessel compared to a new vessel mainly because the adjustments to the existing structure and ship systems arrangement.

In FIRESAFE II study, closure of openings was evaluated, see ANNEX J1 Selected FIRESAFE I & II references.

23.4.3 Aft and forward openings aspects

Aft and/or forward openings are usually arranged from side to side to allow free drive through the cargo space.

Closing of those openings will have direct impact on the design of the cargo space and cargo operation.

23.5 Proposal for development and restrictions

For the permanent closure or temporary closure (in case of fire only) of side opening, a lightweight solution may be considered (for example, made of composite materials).

Aft and forward cargo space openings closure solutions may require a free corridor between decks, side to side, to provide an unobstructed area for the closure appliances. Option could be to find a shutter solution that will follow/adapt to the shape of "obstructing" cargo units. Any shutter installation must not reduce required clear height of cargo decks. Such installation should be preferably fitted within the structure of the deck above (cargo space top). Shutters need to be installed perpendicular to lanes to minimize the loss of the cargo space capacity. Further, the solution must consider the harsh installation environment, frequent operation, risk of mechanical damages and very direct operational consequences if not operable.

Fire resistance performance of closing appliances may be evaluated ("A0" or only "Non-combustible material"). Depending on the requirements, air gaps in closure system may be permitted.

Alternative ship concepts with same or better capacity (total and dangerous goods), preserved efficiency and minimized extra cost/investments need to be investigated. Concepts should seek to avoid adverse impact on stability, lashing forces and evacuation conditions.

One proposal is to map fire performance of current state of the art design proposals from leading ro-pax and ro-ro cargo Naval Architect companies.

24 Ro-ro space ventilation and smoke extraction – Action 11-D

Main author of the chapter: Obrad Kuzmanovic, FLOW

This chapter is giving an overview of the ship integration requirements and applicable regulations for the Action 11-D i.e. Ro-ro space ventilation and smoke extraction.

Determine the effects of natural and mechanical ventilation on fire development, evaluate safety measures and create guidelines.

24.1 Short Description of the addressed Action

The ventilation (both natural or mechanical) is a key factor to the growth, intensity and burning time of fires in ro-ro spaces but effects are not clear and measures for managing ventilation in case of fire are generally missing. Deactivation of ventilation fans and closure of dampers is a standard procedure in case of fire, but this can cause critical accumulation and later spreading of smoke to the accommodations. The goal is to determine the effects of natural and mechanical ventilation on fire development, evaluate current possibilities and new safety measures for smoke containment and create guidelines through:

- Definition of conditions for ro-ro space ventilation
- Evaluation of ro-ro space ventilation and smoke extraction
- Validation of ro-ro space ventilation evaluations

24.2 Regulation review

Main author of the chapter: Blandine Vicard, BV

24.2.1 General

24.2.1.1 Scope

This section aims at giving an overview of the requirements applicable in ro-ro spaces regarding Action 11-D, i.e. "ro-ro space ventilation and smoke extraction".

24.2.1.2 Applicable regulations

The present review is based on the currently applicable regulations. Therefore, some of the requirements detailed below may not be applicable on old ships.

A brief summary of the main regulation changes related to Action 11-D is provided in Table 45

Table 45: Summary of regulation changes

Regulation change	Application date	Adoption date	Summary
SOLAS 74	1980	1974	Introduces the general principle of ventilation for ro-ro and vehicle spaces, including minimum air changes per hour and segregation with respect to other spaces
MSC.365(93)	01/01/2016	22/05/2014	Update of SOLAS requirements for the insulation of ventilation systems (SOLAS II-2/9.7). No major impact for ventilation of ro-ro and vehicle spaces
MSC.392(95)	01/01/2017	11/06/2015	Introduces the option for a reduced number of air changes in ro-ro and vehicle spaces, as detailed in §24.2.2.1.2

Table 46: List of documents used for the review of regulations for Action 11-D

IMO Documents	SOLAS Convention, as amended
	MSC.1/Circ.1120
	MSC.1/Circ.1434
	MSC.1/Circ.1515, Revised design guidelines and operational recommendations for ventilation systems in ro-ro cargo spaces
	MSC.1/Circ.1615, Interim Guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships
IACS & Class Rules	IACS Blue book dated January 2020
	BV Rules for Steel Ships (NR467), as amended in July 2020
	DNVGL Rules for classification, ships, as amended in July 2020
Flag Administration Rules	MMF (French Flag Administration) Division 221 “Passenger ships engaged in international voyages and cargo ships of more than 500 gross tonnage”, 11/01/2020 edition
	US Coast Guard Code of Federal Regulations (CFR) 46, 2019 online edition
	MCA (UK Flag Administration) Guidance on SOLAS Ch.II-2

24.2.2 Requirements

24.2.2.1 Ventilation purpose and required capacity

24.2.2.1.1 General case

Ro-ro spaces are reckoned to be hazardous spaces where an explosive atmosphere may occur – basically due to vehicle fuel vapours. Significant ventilation is therefore required in these spaces as a mitigation measure to avoid ignition of an explosive atmosphere. It is to be noted that other measures are also taken to avoid ignition of explosive gases, including restrictions on possible sources of ignition.

SOLAS II-2/20.3.1.1 [5]requires the following capacity for the ventilation systems of closed ro-ro spaces:

Table 47: Required ventilation rate in closed ro-ro spaces

Type of ship	Ro-ro space	Required ventilation rate [air changes per hour]
Passenger ship carrying more than 36 passengers	Any	10
Passenger ship carrying not more than 36 passengers	Special category spaces	10
	Other closed ro-ro and special category spaces	6
Cargo ships	Any	6

For practical purposes, open ro-ro spaces and weather decks are naturally ventilated and no minimum ventilation capacity is therefore specified.

SOLAS II-2/20.3.1.1

Some Flag Administrations have slightly different requirements. For example, the USCG CFR [46] specify a ventilation rate of $1ft^3$/min for each square foot of deck area of vehicle space, i.e. about 6 air changes per hour considering a typical deck height of 10ft in the vehicle space. They also specify that the ventilation should be of the overpressure type.

USCG 46 CFR 92.15-10 and 46 CFR 72.15-15

The ventilation system shall be such as to prevent air stratification and the formation of air pockets.

SOLAS II-2/3.1.2.3

In addition, a number of Flag Administrations specify a higher number of air changes during loading and unloading: French Flag Administration [47] requires 15 air changes per hour. The USCG [46] require carbon monoxide content to be monitored when vehicles are to be used in enclosed spaces.

MMF division 221 – II-2/20.3.1.1, USCG 46 CFR 97.80-1 & 46 CFR 78.83-1

24.2.2.1.2 Reduced ventilation rate

In case an air quality control system is provided, complying with the requirements of MSC.1./Circ.1515 [48], as detailed in §24.2.2.1.3 below, the ventilation rate may be decreased. It is to be noted that air quality control is based on gasoline vapour and toxic exhaust gas measurements. Therefore, it is not applicable in 3 cases:

- Carriage of dangerous goods (covered by SOLAS II-2/19 [1]): Because SOLAS II-2/19 [5] does not include provisions for hazardous gases generated by dangerous goods;
- Vehicle carrier carrying hydrogen-fuelled vehicles (covered by SOLAS II-2/20-1 [5]): Because hydrogen explosive atmospheres are not considered in MSC.1./Circ.1515 [48]; and
- When an increased ventilation rate (10 air changes per hour) is used as a mitigation measure to reduce the level of protection of the electrical equipment, as allowed by SOLAS II-2/20.3.2.2 [5].

SOLAS II-2/20.3.1.2

24.2.2.1.3 Air quality control system

When provided with a view to operating with reduced ventilation capacity, the air quality control system is to regulate automatically the ventilation rate based on measurements of CO, NO2 and LEL values, so that the threshold values are never exceeded over a 5min period. The threshold values are long-term exposure values and are defined based on ISO 9785:2002 [49], they are reproduced in Table 48. In addition, a visual and audible alarm is to be given at a continuously manned location in case the threshold values for those pollutants are exceeded.

MSC.1/Circ.1515 Appendix 1 §1, 2.1, 2.3, 3.1, 3.2, 4, 6

Table 48 – Pollutant threshold values

Pollutant	Threshold value
CO	40mg/m3
NO2	4mg/m3
Flammable gas	10%LEL

MSC.1/Circ.1515 Appendix 1 §4.2

Detailed provisions are given with a view to:

- Ensuring proper design and location of the sensors for an efficient monitoring of the pollutant level. In addition to general design and considerations, a performance test on board is required – it may be replaced by a model test.

MSC.1/Circ.1515 Appendix 1 §2.1, 2.6, 2.9, 3.1, 3.3, 4.3, 5

- Ensuring proper operation, calibration and maintenance of the sensors and pollutant monitoring system.

MSC.1/Circ.1515 Appendix 1 §2.2, 2.7, 2.9

- Minimizing the risk of loss of power and informing the crew in case of failure, especially power failure of the air quality control system. In this situation, the ventilation system is to return automatically to its nominal capacity, as required without air quality control system.

MSC.1/Circ.1515 Appendix 1 §2.4, 2.5, 2.8, 2.10, 2.11

24.2.2.1.4 Ventilation equipment

In general, ro-ro and vehicle spaces are reckoned as hazardous areas. As a consequence:

- Exhaust fans are to be non-sparking; and
- If located in the exhaust duct, fan motors are to be of an adequate certified safe type. Otherwise, they may be located outside the ventilation duct.

SOLAS II-2/20.3.3 as interpreted by IACS UI SC 43 and MSC.1/Circ.1120

As a complement, UK MCA [50] requires that most of the fans serving ro-ro or vehicle spaces be located in a dedicated space, separated from the ro-ro or vehicle spaces.

UK MCA Guidance on Ch II-2 – G1.1

24.2.2.2 Ventilation controls

For each ro-ro or vehicle space, it is to be possible to:

- Control (i.e. start and stop) the ventilation system; and
- Close all ventilation openings.

From outside these spaces, taking into account weather and sea conditions. Remote control arrangements with position indicators may also be accepted.

SOLAS II-2/20.3.1.2 & 20.3.1.4, as interpreted by IACS UI SC 243 and IMO MSC.1/Circ.1434

In addition, the ventilating capacity is to be monitored from the navigation bridge. An alarm initiated by fall-out of the starter relay of the fan motor is deemed acceptable in this respect.

SOLAS II-2/20.3.1.3, as interpreted by IACS UI SC75 and IMO MSC.1/Circ.1120

24.2.2.3 Testing of the ventilation system

MSC.1/Circ.1515 [48] includes maintenance recommendations for the ventilation system and especially testing recommendations:

- Testing of the ventilation system at ship delivery by a Third Party;
- Testing every year by the ship's crew or operator; and
- Testing by a Third Party every 5 years.

IMO MSC.1/Circ.1515 Annex Part 2 §2 and 3

It is to be noted that Classification Societies' survey requirements [52] and [53] do not explicitly mention testing following the test procedure detailed in MSC.1/Circ.1515 Appendices 2 and 3 [48], rather verification that the ventilation system is in working order at each annual survey.

BV NR467 Rules for the Classification of Steel Ships, Pt A, Ch 4, Sec 6 [2.3]

DNVGL Rules For Classification: Ships, Pt 7, Ch 1, Sec 2 [3.1.17]

24.2.2.4 Operational recommendations

24.2.2.4.1 During normal operation

MSC.1/Circ.1515 [48] includes operational recommendations for the ventilation system and, more generally, avoiding exposing people to polluted air or generating explosive mixtures. These include:

- Ensuring that the air flow will not be impeded (free ventilation inlets and outlets, avoid overcrowded areas and other obstructions);
- Adapt the ventilation air flow to the operational situation and environmental conditions;
- Avoid sending people to carry out unnecessary work during periods when a significant quantity of pollutant can be generated, e.g. loading/unloading; and
- Manage loading/unloading procedures so as to reduce the period when vehicle engines need to be running, with considerations dedicated to each ship type.

IMO MSC.1/Circ.1515 Annex Part 2 §4

24.2.2.4.2 In case of fire

In case of fire situation, there is no specific action requirements from the IMO regulations to activate or shutdown the mechanical ventilation of ro-ro spaces nor to open or close openings. Those actions should be understood as operational and up to on-board procedures or to Master's and/or crew's appraisal depending on the fire situation. Nevertheless, the IMO regulations provide the possibility to perform such actions (as described in the above sections).

24.2.2.5 Fire containment

Ventilating systems are specifically scrutinized when considering fire insulation, as they may be a weak point in this respect. Ro-ro and vehicle spaces are reckoned to be spaces with high fire risk and, in this respect, the following is required for their ventilation systems in order to avoid propagating a fire to other spaces:

- The ventilation systems for ro-ro and vehicle spaces are to be separate from each other and from ventilation systems serving other types of spaces.
- Ducts serving other spaces and crossing ro-ro or vehicle spaces and ducts serving ro-ro or vehicle spaces and crossing other spaces are to be of substantial thickness and either insulated to A-60 standard over their whole length or provided with an automatic fire damper close to the boundary penetrated and insulated to A-60 standard over 5m. For ducts serving ro-ro or vehicle spaces and crossing category A machinery spaces, the first option is mandatory.

SOLAS II-2/9.7.2 & II-2/20.3.1.4.2, as interpreted by IMO MSC.1/Circ.1120

The required automatic fire dampers are to:

- Close automatically, in response to exposure to fire products (e.g. heat);

SOLAS II-2/3.54

- Have a failsafe mechanism that will close the damper in a fire even upon loss of electrical power or hydraulic or pneumatic pressure loss; and

SOLAS II-2/9.7.3.3

- Be manually operable from both sides of the boundary penetrated, i.e. being capable of being closed and re-opened manually.

SOLAS II-2/9.7.3.3

No remote control is required for those dampers.

24.3 Operational aspects

24.3.1 Consideration on closed ro-ro decks

Ventilation system is a significant system onboard in terms of investment, power need, space claim and maintenance. Therefore, it should be carefully designed and optimized according to the design of the individual ship and the operational vehicle handling and exhaust emissions accumulation connected with it.MSC.1/Circ.1515 considers 4 main measures:

- a reduction in exhaust gas emissions,
- provision of an adequate ventilation system,
- limitation of exposure to the gases,
- prevention of accumulation of hazardous and flammable gases.

The operational recommendations are primarily directed at those involved with cargo handling in ro-ro cargo spaces. Their purpose is to suggest ways in which exposure to exhaust gas emissions can be restricted and to avoid accumulation of potentially hazardous and flammable gases. These recommendations can be divided in **four** main parts: **testing of the ventilation system, training and information, inspection, maintenance and repairs and recommendations for cargo operations**.

Some tests are Class requirement and should be performed before the actual delivery of the ship (air change rate), but it is very important to also test the actual air distribution and the air quality in the ro-ro cargo spaces. The testing should be repeated in regular intervals, and in situations which indicate the necessity, whether based on worker complaints or substantial changes in vessel operation. All test results verifying the adequacy of the ventilation system should be documented and kept on board. The ventilation system operation procedures should be established based on mentioned test results and according to the cargo operations.

Furthermore, the personnel should be properly trained and familiarized with established procedures. However, there are no specified procedures, only IMO recommendation to establish it. Usually, first training and familiarization is performed during the actual building and testing process of the ventilation system. A process should be also established to record and investigate complaints for poor air quality by crew and stevedores. Drivers should be given appropriate instructions for embarkation or disembarkation. Training and information should be reviewed following a significant change in the operation of the vessel.

Inspection, maintenance and necessary repairs should be carried out professionally and in regular intervals (annually). Necessary skills, equipment and spares should be always available. Third party testing should be undertaken before entry into service of a new ship and at periodical intervals thereafter.

Loading and unloading operations are by far the most critical operations regarding health hazard. It is therefore extremely important that the ventilation system is operated in the most effective manner under the prevailing operational and weather conditions. The personnel responsible for loading and unloading of vehicles should consult with the officer responsible for vehicle deck ventilation to familiarize himself with the ventilation system on board and decide whether the ventilation is adequate in the light of traffic density, vehicle types and other considerations. It is also important to ensure free passage of supply air and that ventilation openings are not unnecessarily obstructed. Vehicles should spend as little time as possible on board with their engines running. The speed at which the vehicles are driven on board should also be appropriate to the prevailing conditions. Exhaust emissions are greatly influenced by driving techniques and the temperature at which an engine is running. The essential points are as follows, according to the Circ.1515 Part 2:

- condition of the engines
- driving techniques
- organization of the work (as few engines as possible running at the same time)
- the drivers should not start their engines sooner than necessary (in case of unloading)
- ensuring the steady flow of the traffic (eliminating heavy acceleration and high speeds) – little effect during disembarkation due to cold engines.

The drivers should be given printed instructions for embarkation/disembarkation and driving techniques, which is especially important in case of car ferries, see ANNEX K2 Example of instructions to drivers.

Ventilation systems in the **cargo ships** may be operated at **decreased** capacity (SOLAS II-2/20.3.1.2.4) when controlled by a **detection system** that monitors the flammable and harmful gases in the space. Air quality management is based on the measuring and controlling of CO, NO2 and LEL values.

In **cargo ships**, ventilation fans shall normally be run continuously whenever vehicles are on board. Where this is impracticable, they are to be operated for **a limited period daily** as weather permits and in any case for a reasonable period **prior to discharge**, after which period the ro-ro or vehicle space shall be proved gas-free. One or more **portable combustible gas detecting instruments** are to be carried on board for this purpose.

According to STL, WAL and DFDS , the most common way to operate the ventilation system in case of fire is to **turn it off and to close fire dampers**, however, the responsibility remains on captain, whether following the standard procedure or not, after the evaluation of the situation.

Impact of drencher on air circulation must be understood. This could have a significant impact on airflow and temperature of gases during a fire scenario.

24.3.2 Considerations on open ro-ro decks

Please refer to Chapter 23.

24.3.3 Considerations on weather decks

Different weather decks designs give very different ventilation conditions, see ANNEX K1 Weather deck types.

24.3.4 Toxic gases from electric battery car fires

Ventilation of toxic gases from fires in electric cars is essential for the safety of crew, fire squad and passengers.

Also, thermal runaway of a Li-ion battery is independent of oxygen supply, in the sense that the thermal event is not worsened by air flow/ventilation (such as the fire spread from the battery to combustible materials in the surrounding vehicle).

Some investigations propose parking of electric vehicles on open decks or weather decks with natural ventilation. Currently, there is no special treatment of EVs, they are parked as any other vehicle.

Other aspect to consider is leakage of toxic gases to public spaces via openings, ventilation or fire doors on ro-ro deck.

Early detection of gases will be delayed if emissions are moved and/or diluted by air flow. However, such emissions from batteries may be detected faster in the air flow in for example ventilation outlet ducts, having installed very sensitive equipment. Currently, such equipment is not in commercial usage onboard.

In manual firefighting there are items to consider such as if venting the space could reduce toxic environment for fire fighters and contamination of their equipment and clothes. Portable fans could perhaps be used. The organisation behind smoke divers must be looked at to see if they are exposed to dangerous level of toxic gases. These people are often standing unprotected at point of entry (could be in a stairway or other indoor locations), sometimes with the door slightly open towards ro-ro space. Typically, these people are there to provide assistance to the smoke divers in form of equipment, gas bottles, keeping track of time and oxygen level for smoke divers, reporting to officer on bridge/emergency control, assisting smoke divers as they return back from the fire (give water, undress, hold and exchange bottles for the breathing apparatus). Perhaps there is a need for changed routines considering the toxic environment in general but also considering toxic gases from battery fires. Tactical ventilation could be useful tool. There is a paper released in Sweden in August 2020 [54] on how land based fire fighters shall handle indoor garage fires where li-ion batteries contribute to fire load. Ventilation is mentioned and also how to undress and remove protective gear after a fire and some words about contamination of surfaces and equipment. Reading this one realises it differs a bit from ship procedure which is typically to turn of ventilation and no clear instructions on ventilation and contamination of fire fighters clothes and equipment, nor for people assisting the fire fighters.

24.4 Design and production aspects

It is very complex to design the ventilation for a ro-ro space. Every ship is unique and therefore no templates or standard calculations can be used [55]. In Circ.1515 it is clear *that it is not possible to draw up or recommend any universal solutions for the distribution of air flow in different type of ship.* The following general applications are written in the Circular 1515 Part 1:

- *The air flow should reach all parts of the ro-ro cargo space. However, ventilation should be concentrated in those areas in which the emissions of exhaust gases are particularly high and which are occupied by the crew or other workers.*
- *Consideration should be given to the likelihood of unventilated zones being screened behind an object, and also to the fact that exhaust gases readily accumulate in low-lying spaces under the vehicles and in decks beneath the one being unloaded. Furthermore, depending on air flow patterns, it may be possible for contaminants to move into decks above the one actually being offloaded.*
- *The air flow on vehicle deck should be suited to the height of the deck.*
- *The air flow will follow the path of least resistance, and most of the air will thus flow in open spaces, such as above the vehicles, etc.*
- *Polluted air from ro-ro cargo spaces should be prevented from being dispersed into adjacent spaces, for instance accommodation and engine-rooms.*
- *Whenever possible, places which are sheltered from the airflow should be indicated on the plan. The actual locations of such spaces on the deck should be painted in a conspicuous manner to*

indicate that personnel should not stand on that part of the deck, and signs should be hung on the bulkhead to provide a backup warning.

Ventilation systems for ro-ro cargo spaces on board ships generally operate according to the principle of dilution ventilation.

There are two main types of dilution ventilation: exhaust air ventilation and supply air ventilation. In exhaust air ventilation, the air from ro-ro cargo space is removed with fans and air change is ensured by outdoor air entering through open ramps, doors and other openings. Exhaust air ventilation is employed when sub-atmospheric pressure is required in the ro-ro cargo space, which prevents the pollution from spreading to adjacent areas. In supply air ventilation, fans deliver outdoor air into ro-ro cargo space and the air is then exhausted through ramps and other openings. Supply air ventilation usually creates slight pressurization of the ro-ro cargo space. If used exclusively, pollutants may mix with the supply air, be pushed up the internal ramps and contaminate other decks. Besides, contaminants may remain on the deck in question, if not sufficiently mixed with supply air – hazardous conditions may occur on lower decks. Most of the Uljanik shipyard built vehicle carriers and ro-ro ships generally had exhaust ventilation, with the exception of DE ferries and ro-pax ships.

Ventilation system on board ship often combine these two principles, especially when ships has both stern and stem ramps. The fans can also be reversible, but the operator must be aware to the fact that reversible fans cannot obtain full capacity in both modes (supply and exhaust).

Exhaust gas dispersion will never be uniform. It is dependent upon the capacity, design and mode of operation of the ventilation system, also the volume and configuration of the cargo space as well as natural ventilation patterns and location of vehicles in ro-ro cargo spaces. Even though the overall rate of air change on vehicle decks may be high, there will also be areas with low rates of air change and should be located, indicated and painted. Air requirements should be calculated according to ISO 9785:2002 which may be used as reference in the planning of new installations.

In addition to ensure given rate of air changes for certain ro-ro cargo space, it is equally important to ensure proper air circulation in the same space. *Duct runs and the location of supply air and exhaust air openings should be made to suit the design of the individual ship, the estimated vehicle handling and exhaust emissions in such areas. The air flow can be determined by means of direct measurement or by calculation-based methodology (CFD and/or use of established empiric formulae).*

ISO 9785:2002 gives following general considerations for ventilation systems and ducting:

- *supply air and exhaust air openings should be located so that the ventilation will be concentrated to those areas in which the emissions of exhaust gases are particularly high and in which crew work*
- *supply air and exhaust air openings should be located, wherever possible, where they will not be obstructed by the cargo or screened by ship's structure*
- *supply air and exhaust air openings should be designed so that the maximum air velocity in the openings does not exceed 10 m/s (recommendation only)*
- *Considerations should be given to the likelihood of there being unventilated zones screened behind objects, and also to the fact that exhaust gases readily accumulate in low-lying spaces and under the vehicles*
- *the airflow will follow the path of least resistance and most of the air will thus flow in open spaces, such as above for cargo, vehicles etc.*
- *measures should be taken to prevent polluted air from cargo spaces from dispersing into adjoining spaces where people can be exposed, such as accommodation, engine room etc.*

The ventilation system shall be such as to prevent air stratification and the formation of air pockets.

Certain Class Societies (DNV-GL) require independent power ventilation system to be provided for the removal of gases and vapours from the upper and lower part of the ro-ro cargo spaces on cargo ships. This requirement is considered to be met if the ducting is arranged such that approximately 1/3 of the air volume is removed from the upper part and 2/3 from the lower part.

ISO 9785:2002 gives the guidance for estimating the flow of outdoor air required to dilute and remove the exhaust gases and for assessment of the number of vehicles which may be in operation at the same time in a ro-ro cargo space. The guidance specifies the supply air requirement per vehicle, to ensure that the level of pollution is kept below the exposure limit.

In general, the design procedure for ro-ro cargo space ventilation system should include the following measures:

- Satisfy the rules requirements, among others related to required exchange of air (in port and seagoing)
- Optimize the arrangement of ventilation trunks or ducts, i.e. number of trunks, ventilator required properties, etc.
- Avoid interference with other equipment
- Must be easy to operate, preferably from several access points
- Easy maintenance
- Minimize the interference with the cargo area and passenger area

Testing the ventilation system prior to the delivery of the ship must be performed in order to confirm that the design air change and air flow is obtained. The test results apply to empty vehicle spaces and the weather prevailing at the time of testing. But, to utilize the ventilation system in the ro-ro cargo spaces on a ship in most effective way, knowledge should be acquired of its capacity from experience and through simple tests. The factors that need to be determined are the quantities of air supplied to and exhausted from the ro-ro cargo spaces and the circulation of air within the vehicle deck. It is very important that the conditions prevailing at the time of the test, which influence the results, are carefully documented since air flow patterns will vary according to loading conditions.

The rate of air change is a Class requirement test, performed for each vessel, and usually determined by measuring the flow of air on each ventilation opening using a direct reading of anemometer. Sometimes, on Owner's request, the smoke test is performed. The smoke test is a visual test using visible smoke, which provide sufficient indication of a satisfactory picture to be obtained of the air circulation, the existence of any possible stagnant or screened zones and the rate at which pollutants are removed by designed ventilation system.

24.5 Proposal for development and restrictions

A list of the proposals for development and restrictions is divided on proposals in regulations (SOLAS, ISO), from operational and design aspect and few conceptual solutions. These aspects are very closely interdependent, but for the sake of clearer report, they will be distinguished.

First of all, regarding regulation aspect, the interpretations, especially in SOLAS, should be written in clearer manner. The classification of ro-ro cargo spaces should be better defined as well as the definition and description of "side". Further, clear guidance of how to calculate the openness of an open ro-ro cargo space shall also be included, to avoid different Class interpretations and a background of open ro-ro cargo space definition regarding 10% of the total area of the space sides should be mathematically revised. The decision whether the openness of the space sides in closed ro-ro cargo spaces variating from **4-9%** to be **completely banned** (almost as vulnerable as an open ro-ro cargo space in case of fire incident, as concluded in RISE RO5 project) should be considered.

Regulation SOLAS II-2/20.3.1.2.4 states that the minimal ACPH may be decreased if air quality control system is implemented, however if minimal ACPH is 10, this relaxation may not be applied.

This basically means that ship owners and operators that are ready to go beyond the Rules and Regulations in order to increase fire safety on their ships investing in such technologies monitoring the air quality in the ro-ro cargo spaces, will have no bonus comparing to the others simply following the minimal Rules. It will be interesting to know what the reason for this decision was.

A future application of use of air quality-controlled ventilation may enable both less installed ventilation capacity and/or operation on reduced flow levels if such saving would support financing RCOs.

Air quality control systems with highly sensitive sensors should be investigated to be linked to gas detection and fire detection systems, in order to get early indications of a smoldering fire, gas leakage or for example a damaged battery emitting typical gases before a thermal runaway starts.

Permanent openings have very general requirement about their longitudinal location, as per SOLAS II-2/20.3.1.5. Other than that, nothing else can be found in SOLAS regarding permanent openings for natural ventilation, concerning geometrical shape, size, position etc. It is already investigated what is preferable shape in case of fire development (RO5). It shall be clarified in SOLAS what is included in the definition of "permanent openings".

The method for assessment of supply airflow for ro-ro cargo spaces from ISO 9785:2002 considers the degree of estimated dilution of the air pollution in the cargo spaces, as well as average values of pollutants in exhaust gases from different vehicles on board ships. These values seem to be outdated and should be checked and revised, if needed. The alternative powered vehicles (APV), such as LNG, CNG and battery-powered vehicles should be also considered and included.

From operational and design aspects, it will be most interesting to continue to study effects of the possibility to activate the mechanical ventilation in case of fire instead of completely shutting it down which is a today standard in most shipping companies, as well as further research of the effects of ventilation on fires in combination with a fixed fire extinguishing system. Forced ventilation may improve visibility conditions for firefighters, but it remains to be investigated whether the safety benefits would outweigh the adverse effects of increased temperature and fire spread from the supply of fresh air.

It will be interesting to investigate if there is any benefit from predefining (in software) ventilation/damper operation scenarios for different fire scenarios to support fast decisions and action in a situation.

Fixed CO2 firefighting systems require fan stop and closing of all openings in order to achieve the inerting effect. Decision for release of CO2 must be made early in order to minimize the fire spread (Ref. Chapter 18).

Worth considering is also what will be impact on fans/dampers etc from operation with hot fire gases in case that evacuation of smoke is performed and what is impact of release of hot/toxic fire gases on outside of vessel.

The introduction of fixed jet fans or portable fans is the new way of improving the work environment for the ship fire team and to prevent the spread of smoke to other ship spaces. The fan capacity, size, characteristics as well as tactic and methodology for the fire teams could be investigated, as well as with respect to safeguarding the support team assisting smoke divers in immediate vicinity to the fire.

Effect of activated drencher system should also be included in a fire simulations to make a realistic scenario which will lead to realistic results and conclusions.

Alternative ship concepts with same capacity (total and dangerous goods) preserved efficiency and minimized extra cost/investments need be investigated. Concepts should seek to avoid adverse impact on stability, lashing forces and evacuation conditions.

One proposal is to map fire performance of current state of the art design proposals from leading ro-pax Naval Architect companies. In other words, it will be interesting to compare different ventilation arrangements from different design companies, more or less similar and typical for ro-ro space designs and to determine which one is more “fire-friendly”, assuming that all of them are similar regarding ventilation performance in normal conditions.

Health and safety aspect need be kept in mind both for normal operation and fire situation.

25 Conclusion

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Specific input was provided to the LASH FIRE development teams, addressing a total of twenty challenges, also called actions, for all stages of fires originating in ro-ro spaces. The design, production, operational and environmental aspects, applicable rules and regulations for all types of ro-ro ships and all types of ro-ro spaces were considered. Finally, expectations and proposals for the developments were given. This ensured a good starting point for the development teams, thus making a clear picture of the end user requirements, and definition of the scope and required functions for the solutions to be developed.

This report contributes to the strategic objective 2:

> *LASH FIRE will evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces.*

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27 Indexes

27.1 Index of tables

Table 1: List of documents used for the review of regulations for Action 6-A....................................12
Table 2: List of documents used for the review of regulations for Action 6-B....................................19
Table 3: List of documents used for the review of regulations for Action 6-C....................................26
Table 4: Minimum inspection and maintenance plan for first response equipment according to IMO MSC.1/Circ.1432 [5]....................................29
Table 5. List of documents used for the review of regulations for Action 6-D 37
Table 6. Idea of a AVF drive line type characteristics overview. 45
Table 7. Summary of regulation changes....................................48
Table 8. List of documents used for the review of regulations for Improved fire detection system interface design 49
Table 9: Monitoring and control requirements according to the different locations (X: Monitoring and control required, Blank cell: Not required) 54
Table 10: List of documents used for the review of regulations for [Objet] 66
Table 11: Summary of regulation changes....................................71
Table 12: Summary of regulation changes....................................80
Table 13: List of documents used for the review of regulations for Action 7-C....................................81
Table 14 - Functionality of systems to be located in onboard safety centre functional requirements.84
Table 15: List of documents used for the review of regulations for [Objet] 98
Table 16: Table of segregation of cargo transport units on board ro-ro ships 99
Table 17: List of documents used for the review of regulations for Action 8-B....................................105
Table 18. Ro-Ro cargo ship painting scheme 1 (for heavy cargo)....................................116
Table 19. Ro-Ro cargo multipurpose ship painting scheme 2 (container, various cargo and vehicle carrier)....................................116
Table 20. Vehicle carrier painting scheme 1 117
Table 21. Vehicle carrier painting scheme 2 117
Table 22. RoPax coating painting scheme....................................118
Table 23. Summary of regulation changes....................................126
Table 24. List of documents used for the review of regulations for Detection on weather decks 127
Table 25. Summary of regulation changes....................................132
Table 26. List of documents used for the review of regulations for Detection in closed and open ro-ro spaces....................................133
Table 27: Spacing of detectors (FSS Ch. 9 Table 9.1) 136
Table 28: Monitoring and control requirements....................................139
Table 29: List of documents used for the review of regulations for Action 9-C....................................150
Table 30. Summary of regulation changes....................................156
Table 31. List of documents used for the review of regulations for [Objet] 157
Table 32 – Minimum horizontal clearances between passenger cars and structures....................................159
Table 33. Structural and clear heights on different decks of a vehicle carrier – example.................163
Table 34. List of documents used for the review of regulations for Action 10-B 168
Table 35 – Minimum horizontal and vertical clearances between passenger cars and structures on ro-pax ships....................................181
Table 36 – Minimum horizontal and vertical clearances between trailers and structures on ro-pax and ro-ro cargo ships. 181
Table 37 – Minimum horizontal and vertical clearances between passenger cars and structures on vehicle carriers and ro-ro cargo ships. 181

Table 38. Structural heights at Stena Flavia 187
Table 39. Structural heights at Magnolia seaways 188
Table 40. Summary of regulation changes 194
Table 41. List of documents used for the review of regulations for Action 11-A 194
Table 42. Fire integrity requirements around ro-ro or vehicle spaces 196
Table 43: List of documents used for the review of regulations for Safe evacuation and SRTP 203
Table 44: List of documents used for the review of regulations for Action 11-C 210
Table 45: Summary of regulation changes 216
Table 46: List of documents used for the review of regulations for Action 11-D 217
Table 47: Required ventilation rate in closed ro-ro spaces 217
Table 48 – Pollutant threshold values 218

27.2 Index of figures

Figure 1. Comparison of amounts of released gas components from fully burned cars of EV and ICE type. 43
Figure 2. Tyco Minerva T2000 system 59
Figure 3. Salwico Fire detection system, SG9812_FDS_RF 59
Figure 4. Fire detection indicator 60
Figure 5. Inert gas system (High pressure CO2) for use in the Engine room on a ro-rax ferry 72
Figure 6. Active drencher system on a car deck 75
Figure 7. Drencher system- Control panel and markings 76
Figure 8. The seven steps of firefighting on board 86
Figure 9. Actions and information flow on a ro-ro vessel 89
Figure 10. Muster Plan Magnolia Seaways 91
Figure 11. Fire detector panel, Pearl Seaways 92
Figure 12. Fire detection panel – close-up, Pearl Seaways 93
Figure 13. A leader keeping track of all personnel-units on the vessel and writing logbook of events 94
Figure 14. Fire drill, Pearl Seaways 94
Figure 15. CCTV panel on bridge, Pearl Seaways 95
Figure 16: Illustration of segregation requirements on ro-ro ship (for the situation Closed versus Closed) extracted from MSC.1/Circ.1440 100
Figure 17. Proposed smart tags for detecting temperature, gas and biochemicals. 104
Figure 18 Insulation fault locating system principal 111
Figure 19 Example of PTC equipment installed on sockets power supply line 112
Figure 20 Use of PCT on reefer container 113
Figure 21. Anti-skid surface example 119
Figure 22. Car deck composite panel - sketch 120
Figure 23. Car deck composite panels 121
Figure 24. Plywood car deck panels 122
Figure 25. Sprayed-on insulation 124
Figure 26. Spray-gun with 3-way nozzle 124
Figure 27. – Stena Transit/Transporter - Alpha Heat Detection System 130
Figure 28. Early detection of fires - example 148
Figure 29. Cargo decks and gas tight zones (vehicle spaces) on a vehicle carrier – example. 161
Figure 30. Scupper arrangement on a vehicle carrier – example. 162
Figure 31. Bilge system in a lower hold of a vehicle carrier – example. 162
Figure 32. Clear height (CL. H.) - example 163
Figure 33. Magnolia Seaways – Fire-protection appliances plan (Weather deck detail) 171
Figure 34. Magnolia Seaways – Weather deck view 171

Figure 35. Stena Jutlandica - Weather deck Fire monitor....172
Figure 36. Ro-pax with large weather deck aft....173
Figure 37.Typical ro-ro weather deck drainage arrangement....175
Figure 38. Typical Scupper detail on a ro-ro weather deck....176
Figure 39. Heavy duty fire-fighting drone (1)....178
Figure 40. Heavy duty fire-fighting drone (2)....178
Figure 41. Full loaded weather deck on a ro-ro cargo ship....182
Figure 42. Example of loading on a ro-pax ship....182
Figure 43. Typical cargo stowage on ro-pax and ro-ro ships (1)....183
Figure 44. Typical cargo stowage on ro-pax and ro-ro ships (2)....183
Figure 45. Typical cargo stowage on ro-pax and ro-ro ships (3)....184
Figure 46. Typical cargo stowage on ro-pax and ro-ro ships (4)....184
Figure 47. Example of loading on a vehicle carrier....185
Figure 48. Example of loading on a vehicle carrier below a hoistable deck....185
Figure 49. Stena Flavia ro-pax - Midship section....187
Figure 50. Magnolia Seaways ro-ro cargo - Midship section....188
Figure 51. Typical vehicle space on a ro-pax ship (photo from Stena Flavia)....189
Figure 52. Typical vehicle space deck structure arrangement with insulation....189
Figure 53. Typical vehicle space on a ro-ro cargo ship....190
Figure 54. Typical vehicle space on a ro-pax and ro-ro cargo ship with movable deck arranged....190
Figure 55. Torrens - Midship section....191
Figure 56. Typical ro-ro space (1)....200
Figure 57. Typical ro-ro space (2)....201

ANNEXES

ANNEX A

Annexes related to Action 6-A Manual screening of cargo hazards and effective fire patrols

Annex A1: Extract from Stena Line “ro-ro space Fire safety – Philosophy”

1.2 Screening for high risk cargo

Reduce fire hazards from i.e. substandard electrical installations, open windows, over heated vehicles, portable fuel containers or added fuel tanks, stowaway activities, open gas tank valves on RVs, insufficient visible cargo lashing and other obvious fire hazards.

1.2.1 Each ship shall have a procedure on how to screen and reject or handle accepted high risk cargo not covered by the IMDG code. This procedure shall include where to locate identified high risk cargo (according to high risk cargo loading guideline, see also section 1.3) and actions such as intensified fire patrol or fire watch. Screening shall be done during loading. This could include help from shore organization if available.

1.2.2 The Company shall develop a training program for recognizing high risk vehicles.

1.2.3 This training program shall provide sufficient knowledge/confidence for a crew member and shore personnel where applicable, to identify, reject or relocate a high risk vehicle.

1.2.4 The training program shall cover, but not be limited to:

- ✓ fire risk awareness and relevant incident statistics
- ✓ screening of cargo units during loading (in particular reefer units and accompanied trailers) awareness of smell, damaged vehicle, heat radiation, leakage
- ✓ cover upon check-in (unaccompanied) for awareness of smell, damaged vehicle, heat radiation, leakage.
- ✓ "smart" electrical installations, e.g. griddles, electrical Christmas decorations, heaters etc.

Project no 935 Page 4

- ✓ open windows (closed windows could mitigate fire growth)
- ✓ late arrivals (overheating)
- ✓ portable fuel containers or added fuel tanks with a hose to the conventional fuel tank (should be refused or stored in a safer location, also spare gas tanks on RVs)
- ✓ stowaways (suspicious noises etc.)
- ✓ open gas tank valves on RVs
- ✓ insufficient visible cargo lashing
- ✓ hazards connected to vintage cars, rebuilt cars, enthusiast cars and wrecked/damaged cars.
- ✓ large amounts of collected combustible materials (e.g. wood chips, hay and debris) in particular by hot surfaces
- ✓ old/used hydraulics equipment, etc.
- ✓ awareness of factors which give increased risk of fuel leakage (fuel price difference between countries, hot days, heavy seas, on tilted ramps, on main deck, etc).

> **Awareness box: High Risk Cargo**
>
> High risk cargo is defined in this document as reefer units, gas vehicles, electrically connected vehicles, vehicles with smart electrical installations or other vehicles or cargo that by a competent person has been identified to have an increased fire risk.

1.11 Effective fire patrols and rapid response

Establish effective fire patrol and rapid response to prevent, detect and safe respond to fires in due time.

1.11.1 There shall be personnel appointed to cover the roles as *fire patrol* and *rapid response*, see description below. The role as rapid response can only be assigned to personnel that can, in case of an emergency, leave their other duties aside immediately.

> **Awareness box: Fire sizes**
>
> A fire of medium growth rate reaches 50 kW after 1 minute. This is comparable to a burning paper bin and is easy to extinguish with a portable extinguisher. After 3 minutes the fire is significantly larger; 400 kW.
>
> After 5 minutes it is about 1 MW which is the size of a 1 m^2 diesel pool fire. Now it is difficult to put out with portable fire extinguishers.
>
> The fire growth is exponential which means that after just another 2 minutes the fire has doubled in size to become a 2 MW fire.

1.11.2 *Fire patrol* appointed personnel shall be trained to detect plausible fires before they develop into actual fires and to take appropriate response actions.

1.11.3 *Rapid response* appointed personnel shall be ready at all times to quickly and safely approach a detected fire and take proper actions to report and if possible extinguish a fire. When a fire is detected, rapid response appointed personnel shall be at the location of the incident ready for a safe approach within 1 minute as target time. The same response time should not exceed 3 minutes.

1.11.4 Personnel appointed as rapid response shall as outer layer clothing, when approaching a plausible fire, wear long sleeve jacket/shirt and long trousers in a material that is not easily combustible. Typically coverall material is good but fleece and polyester is not recommended. Clothing shall be clean, not stained with oily content or similar that increase combustibility. A set of thin material protective long sleeve gloves and safety footwear should also be worn when approaching a fire. Idea is to cover bare skin as much as possible. A radio for communication should always be carried.

1.11.5 Fire patrol clothing and equipment shall be same as for rapid response since it is expected that the fire patrol carry out rapid response tasks when a fire is detected during patrol. Fire patrol shall also be equipped with a flash light and hand held heat camera.

1.11.6 The fire patrol and rapid response shall be aware of vehicle main switch existence (see 1.5) and common locations and labeling to be able to switch off main power in case of an emergency.

1.11.7 Fire patrol and rapid response shall be trained to start the drencher system if requested by person in charge.

1.11.8 Each ship shall have a fire patrol procedure covering schedule, route, responsibilities and equipment for fire patrol. Procedure shall include at what intervals high risk cargo is patrolled. Schedule for fire patrolling shall for each ship be based on:

- ✓ Awareness on typical car fire development scenarios (see awareness boxes on incipient phase and fire development).
- ✓ Ships high risk cargo loading guideline with regard to positioning of more high risk cargo. (Good cargo planning and positioning of units will make fire patrol more efficient so that more attention can be given to areas and units of higher risk.)
- ✓ Awareness that there is a higher risk of a fire incident within the first 1,5h after departure.
- ✓ Awareness that fires are more likely to occur upon arrival.

1.11.9 Each ship shall have a procedure covering rapid response responsibilities and equipment.

1.11.10 Stena shall develop a central training package (E-learning) for fire patrol and rapid response training:

- ✓ Screening of vehicles same as 3.1
- ✓ General awareness of what are the most likely fires to occur onboard cargo deck.
- ✓ Training to identify fire hazards, awareness of smell, smoke, damaged vehicle, heat radiation, leakage, electrical malfunctions and how to respond quick to fire in various cargo, e.g. to turn off main power of bus or disconnect main power of reefer unit before extinguishing etc.
- ✓ Appropriate clothing.

- ✓ Safe fire approach, how to open doors, how to open and use/direct portable fire extinguishers, what other risks can be connected to a rapid response (turn of main switch, pull out electrical cables), not to approach burning gas vehicles, to be familiar with loading plan with regard high risk units.

1.11.11 Fire drills on board should include, but not limited to, quick rapid response. This should typically include:

- ✓ Train for reaching different decks from different entrances.
- ✓ Train when ship is full with cargo.
- ✓ Train to have the rapid response ready to safely approach, report and start extinguishing a small fire within one minute.
- ✓ Train firm and clear communication and the importance of using predetermined terminology.
- ✓ Equipment handling such as heat camera and gas detectors.

Awareness box: Incipient phase and fire development

A normal compartment fire typically has four phases; incipient phase, growth phase, fully developed phase and a decay phase. The incipient phase is an initial period with a small, often smoldering, fire.

If the fire patrol passes during an incipient fire it is likely that the fire will be detected and easily extinguished. Assuming that the incipient phase of a vehicle fire is uniformly distributed between 0 and 60 minutes, then the probability that the fire patrol passes during an incipient phase of a fire can be calculated for varying fire patrol frequencies, see Table 1.

Patrol frequency	Estimated probability; patrol passing during incipient phase
30 min	75%
60 min	50%
2 hours	25%
5 hours	10%

Table 1. Estimated probabilities for fire patrol to be present during the incipient phase at varying fire patrol frequencies.

ANNEX A2 - Stena Line SMM instruction "Fire and Security Patrol at Sea"

Fire and Security Patrol at Sea				Stena Line
Version No.	Revision Date.	Document ID. SMM-0172	Page.	

SMM chapter: 7.2 **ISM reference:** 7

Validity: All vessels

Scope

This document covers the requirement to establish effective security and fire patrolling to prevent, detect and alert personnel to fires and security related issues in due time, whilst the vessel is at sea.

General

Whilst the vessel is at sea the OOW is to ensure that fire patrols of all decks and spaces are carried out and in particular to any area of risk not covered by a fire detection system. The OOW is also to ensure that security is maintained as per the Ships Security Plan and that a security patrol of all decks and spaces is carried out at suitable intervals.

The fire patrol shall also act as a rapid responder that can quickly respond to a fire or potential fire situation. The fire patrol shall be able to safely approach a detected fire and take proper actions to report and if possible extinguish the fire. When a fire is detected, the fire patrol shall aim to be at incident location ready for a safe approach within three minute as target time.

Rounds

Each ship shall have a fire patrol procedure covering the schedule, route, responsibilities and necessary equipment to carry out the fire patrol. The procedure shall include at what intervals high risk cargo is patrolled. The schedule for fire patrolling shall for each ship be based on:

- Awareness on typical car fire development scenarios.
- Ships high risk cargo loading guideline with regard to positioning of more high risk cargo. (Good cargo planning and positioning of units will make fire patrol more efficient so that more attention can be given to areas and units of higher risk.)
- Awareness that there is a higher risk of a fire incident within the first 1,5h after departure.
- Awareness that fires are more likely to occur upon arrival.
- *Consider random checks of gas bottle being turned off*

Training

Fire patrol appointed personnel shall be trained to detect plausible fires before they develop into actual fires and to take appropriate response actions. Each member of a fire patrol is to be trained to be familiar with the arrangements of the vessel as well as the location and operation of any equipment he/she may be called upon to use, especially to start and operate the drencher system.

Equipment and clothing

The Fire and Security patrol shall be equipped with radio communication, a flash light and hand held heat camera. Outer layer clothing shall be worn when approaching a plausible fire. This should consist of a long sleeve jacket/shirt and long trousers which is made of a material that is not easily

Fire and Security Patrol at Sea			
Version No.	Revision Date.	Document ID. SMM-0172	Page.

combustible. Clothing shall be clean not stained with oily content or anything else that will increase combustibility. Safety foot wear with socks should be worn. The philosophy is to cover bare skin as much as possible.

Recording

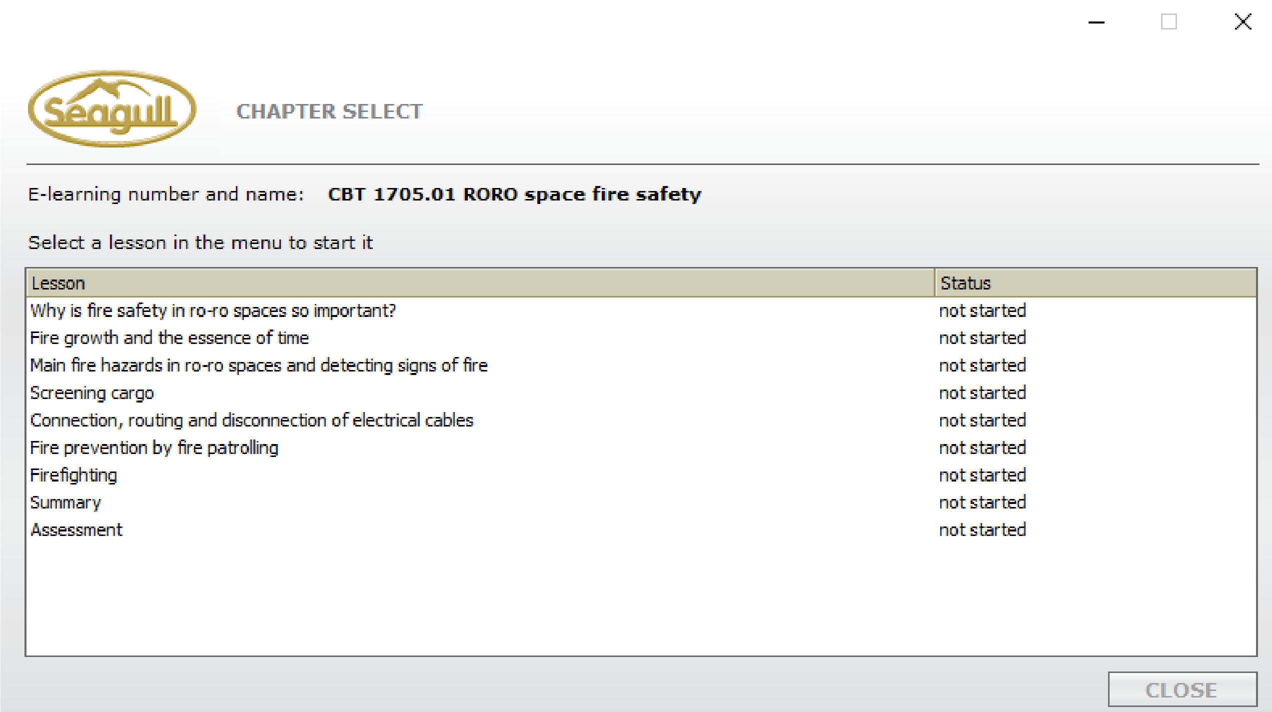
The use of a Fire and Security Patrol round recording system, either electronic or otherwise should be used to enable the patrol records to be stored for inspection.

ANNEX A3 – Stena "Loading Management Manual for High Risk vehicles"

Screening of high risk vehicles

Before any high risk vehicle is loaded on board, a quick screening of the unit shall be done. The screening typical focus on the status of reefer units, awareness of smell, damage to vehicle, heat radiation and any leakage. Personnel assigned for screening duties shall have completed the screening training provided by the Company.

ANNEX A4 – Stena E-learning for fire patrol crew or similar

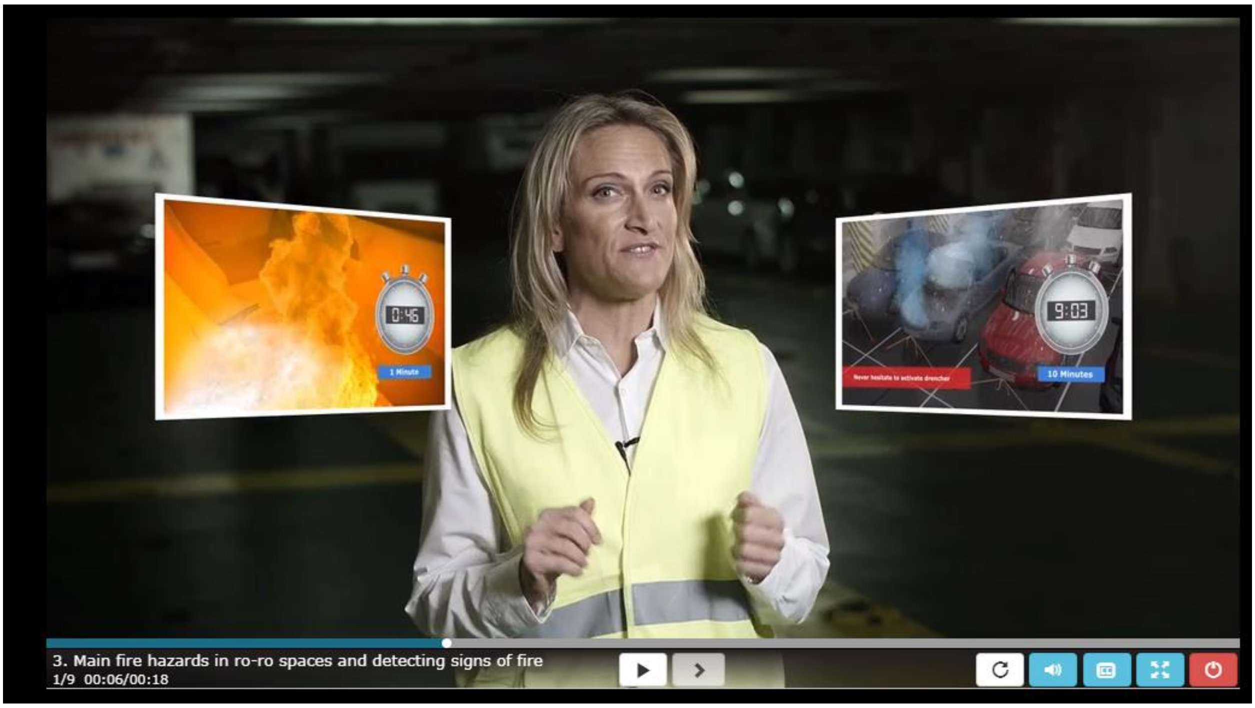

CHAPTER SELECT

E-learning number and name: **CBT 1705.01 RORO space fire safety**

Select a lesson in the menu to start it

Lesson	Status
Why is fire safety in ro-ro spaces so important?	not started
Fire growth and the essence of time	not started
Main fire hazards in ro-ro spaces and detecting signs of fire	not started
Screening cargo	not started
Connection, routing and disconnection of electrical cables	not started
Fire prevention by fire patrolling	not started
Firefighting	not started
Summary	not started
Assessment	not started

CLOSE



Annex A5 – Port operations procedure for Refrigerated cargo trailer

	Port Operation Procedure Type 3 Fridged Trailer	Issue: 2	Page 1 (2)
Stena Line	Karlskrona- Gdynia	Date: 2017-05-12 Replaced: N/A	Sign: Operation Manager

4.1.3.1 ROUTINE TYPE 3 FRIDGED TRAILER
Routine for Type 1 or 3 to be followed and extra for fridged trailer

Check-in
- Bookings are made in Freightlink including the required goods temperature is noted in documents The booking also state of unit is to be runned on diesel or plugged in with electricity in port

Parked Export Area
- The unit will be put on line up area by the driver
- Driver is responsible to set unit running on the own cooler engine or plugged in with electricity according to booking. Plug in electrical cable must be done by assistance of stevedores
- When unit is dropped in port driver make sure aggregate is fully functional and unit in correct temperature

Temperature Check
- To be carried out and logged according to booking in Freight Link

Loaded by tugmaster
- When loaded on vessel ships crew responsible for **electricity plug in** and set unit in "cabels mode" and temperature check

Temperature check on vessel
- During the crossing several safety inspection rounds, including aggregate and temperature control are being made by ships crew

Unlashing Electricity Plug Out
- Just before arrival ships crew disconnect cables and switch to "diesel aggregate mode" and make sure running

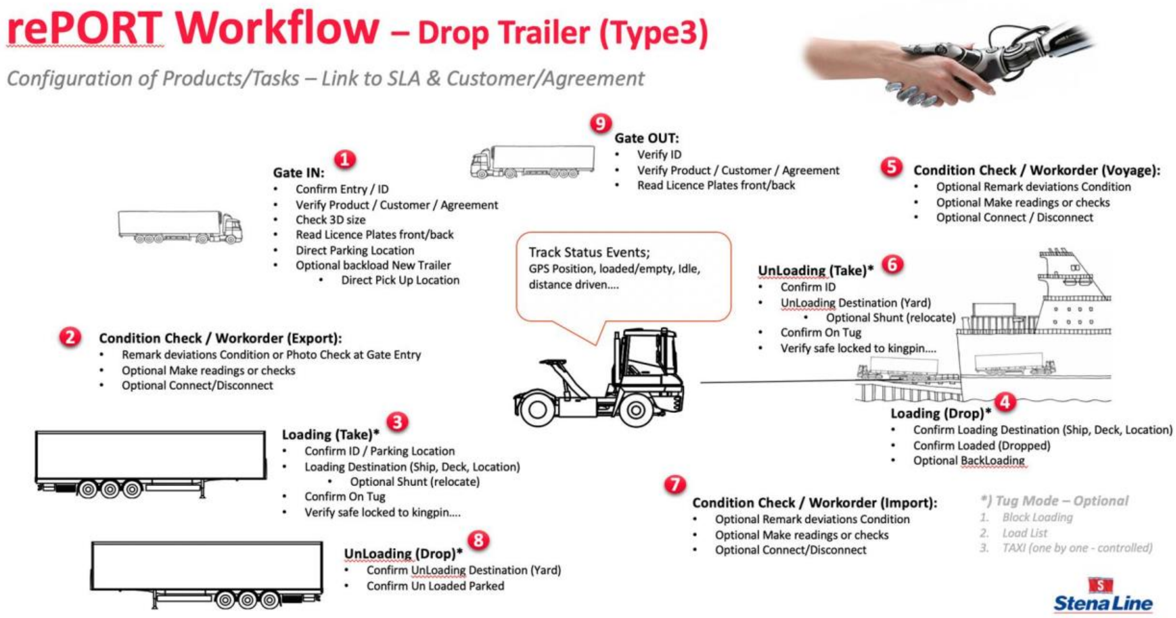
Parked Import Area
- Stevedore check unit is in "diesel aggregate mode" or connect cables according to booking in Freightlink and temperature check.

	Port Operation Procedure Type 3 Fridged Trailer	Issue: 2	Page 2 (2)
Stena Line	Karlskrona- Gdynia	Date: 2017-05-12 Replaced: N/A	Sign: Operation Manager

RISKASSESMENT

Fault	Location	Action
Unit not run on "cabels mode" on vessel	Vessel	Unit to be unplugged and set in "diesel aggregate mode". To avoid exhausts on cargodeck unit to be runned by diesel intermittent to keep temperature Extra safety round to be done by crew Driver or customer to be contacted
Unit not run on "cabels mode" or "diesel mode"	Vessel	Driver or customer to be contacted
If temperature drop	Vessel	Driver or customer to be contacted
Unit not run on "diesel aggregate mode" in port	Port	Driver or customer to be contacted
Unit not run on "diesel aggregate mode" or "cabels mode"	Port	Driver or customer to be contacted
If temperature drop	Vessel	Driver or customer to be contacted
Temperature is unknown at booking time	Terminal	Company must tell when they book. It should be forced when they book to tell the temperature in the system, or we ask them during check-in

Annex A6 – Stena cargo handling workflow management



Annex A7 - Fire and Security Patrol at Sea (Stena Flavia)

Fire and Security Patrol at Sea (Stena Flavia)				
Version No. 1	Revision Date. 2018-06-01	Document ID. SOM-1002	Page. 1	Stena Line

SOM chapter: 7 **SMM reference:** SMM-0172

Validity: Stena Flavia

There shall be an efficient patrol on board to ensure that an outbreak of fire can be promptly detected.

The OOW whilst vessel is at sea is to ensure that fire patrols of all decks and spaces are carried out, especially to any areas not covered by a fire detection system.

Fire Hazards

The greatest hazards associated with vehicle deck fires are:

- Cargoes of Dangerous Goods
- Reefer Units
- Alternative fuelled vehicles (e.g. LNG, battery, hydrogen, hybrids etc.)

There is a higher risk of a fire incident within the first 1,5h after departure.

Equipment and clothing

The Fire- and Security patrol shall be equipped with radio communication, a flash light and hand held heat camera. Outer layer clothing, when approaching a plausible fire, shall be worn. Long sleeve jacket/shirt and long trousers in a material that is not easily combustible. Clothing shall be clean not stained with oily content or other that increase combustibility. Safety shoes with socks should be worn. Idea is to cover bare skin as much as possible.

Recording

The vessel uses an electronic Fire / Security Patrol round recording system to record the patrol. Records are stored on the Chief Officer computer in the Ships Office.

Patrol Schedules

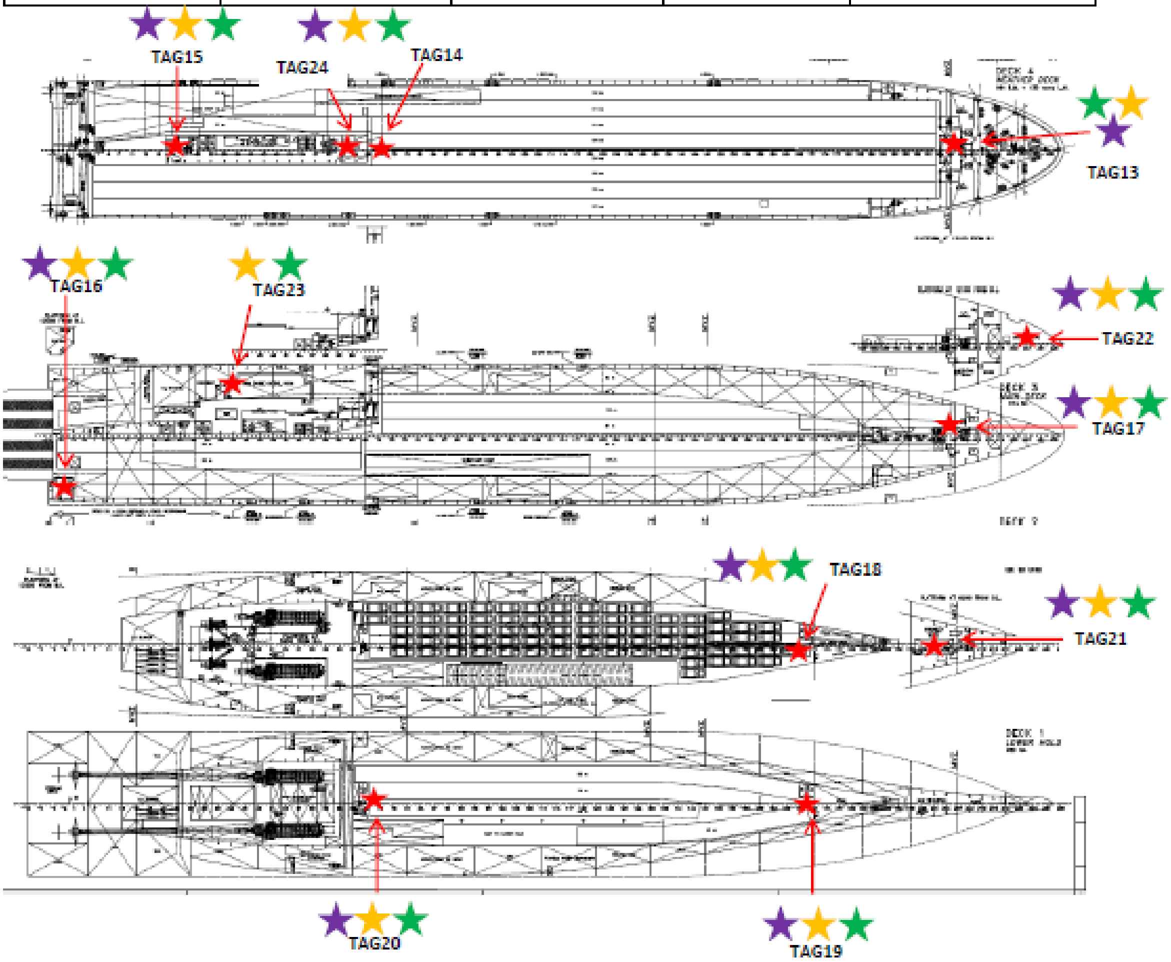
Fire Patrol at Sea:	Fire Patrol in Port:
Departure: **As soon as practical possible after departure – fire patrol on loaded car decks.**	**No fire patrol during short port stay.**
Departure + 1 hour: Fire Patrol	
Departure + 2 hours Fire Patrol	
Departure + 3 hours Fire Patrol	**Long port stay or during layup - use 2 hour schedule.**
Departure + 4 hours Fire Patrol and the rest of the voyage: 2 hour schedule	

Fire and Security Patrol at Sea (Stena Flavia)			
Version No. 1	Revision Date. 2018-06-01	Document ID. SOM-1002	Page. 2

Tag Locations and Frequency

FIRE & SAFETY ROUND TAG LOCATIONS							
START/END point DK7 - Tag 01 Bridge Close to Fire Panel				Tag 23 Engine Control Room			
DK7 Tag 02 STBD Alleyway by Door 145				DK4 Tag 24 Engine Stairs (in Funnel)			
DK7 Tag 03 STBD Alleyway Laundry				DK5 Tag 25 Pullman Lounge (Reception)			
DK6 Tag 04 Fwd stbd alleyway Dr 129 / Store 9				DK6 Tag 26 port Entrance 6225			
DK6 Tag 05 Fwd mid alleyway Dr 6129				DK6 Tag 27 Aft Stbd alleyway Dr 6201 Fitter workshop			
DK6 Tag 06 Fwd port alleyway Dr 6166 / Store 6				DK8Tag 28 Inside Fire Locker No5			
DK6 Tag 07 Fwd port alleyway Dr 6179				DK7 Tag 29 Outside Hospital			
DK6 Tag 08 Fwd mid alleyway Dr 6155				DK7 Tag 30 Crew Mess			
DK5 Tag 09 port Restaurant Entrance				DK7 Tag 31 PORT Alleyway Door 707			
DK5 Tag 10 Galley Entrance by Bar							
DK5 Tag 11 Galley Entrance Dry Store							
Dk5 Tag 12 Restaurant Exit stbd Stairs							
DK4 Tag 13 Forecastle Entrance							
DK4 Tag 14 ETO Shop in Centre Casing							
DK4 Tag 15 PAX Stairs Landing							
DK3 Tag 16 Cargo Office ER Entrance							
DK3 Tag 17 FWD Outside Door 67							
DK2 Tag 18 Car Deck Inside WT Door							
DK1 Tag 19 Lower Hold Inside WT Door							
DK1 Tag 20 Lower Hold Aft							
Tag 21 Bow Thrust Space							
Tag 22 Bosuns Store							

Fire and Security Patrol at Sea (Stena Flavia)				Stena Line
Version No. 1	Revision Date. 2018-06-01	Document ID. SOM-1002	Page. 4	

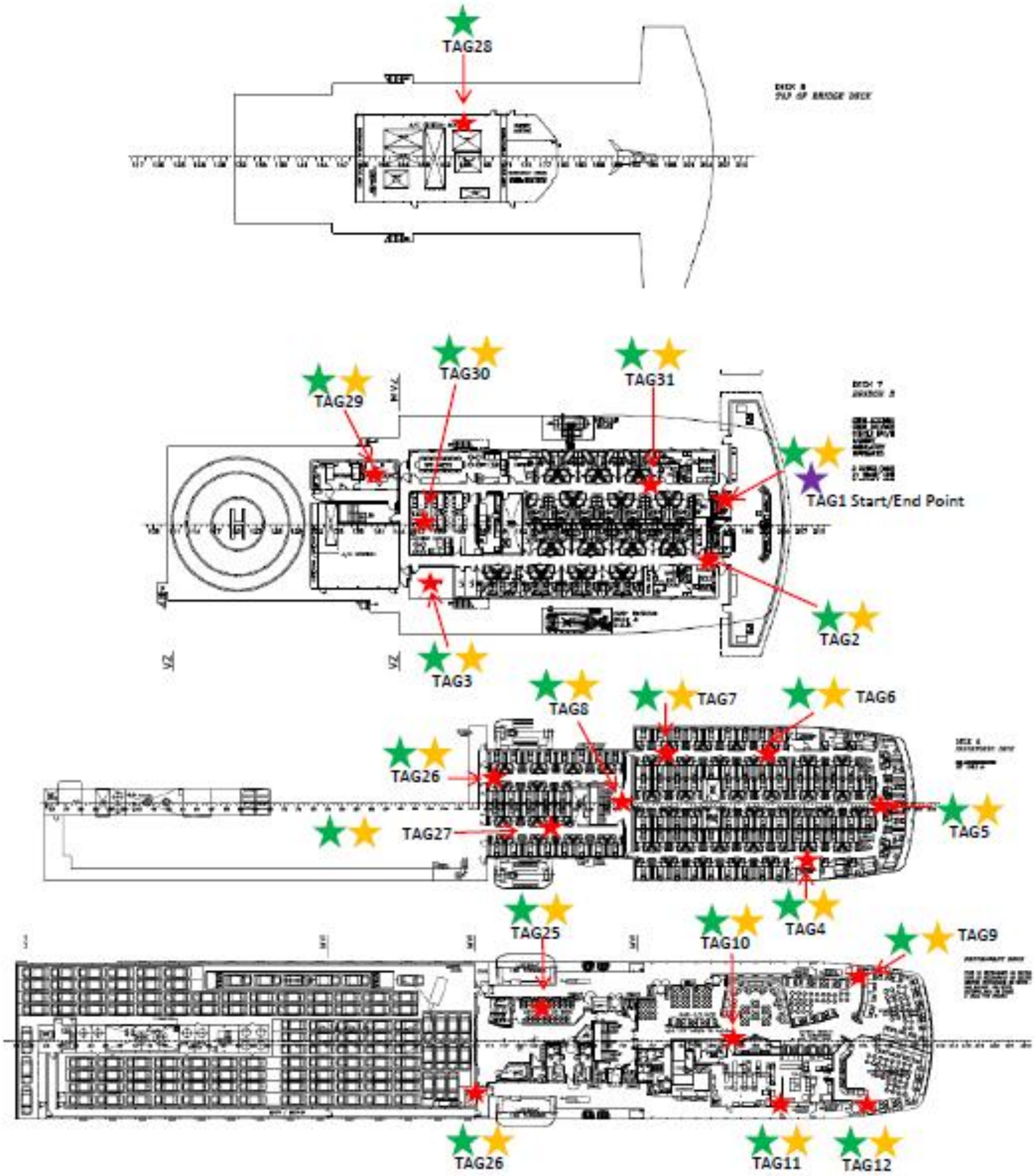


Ref.:

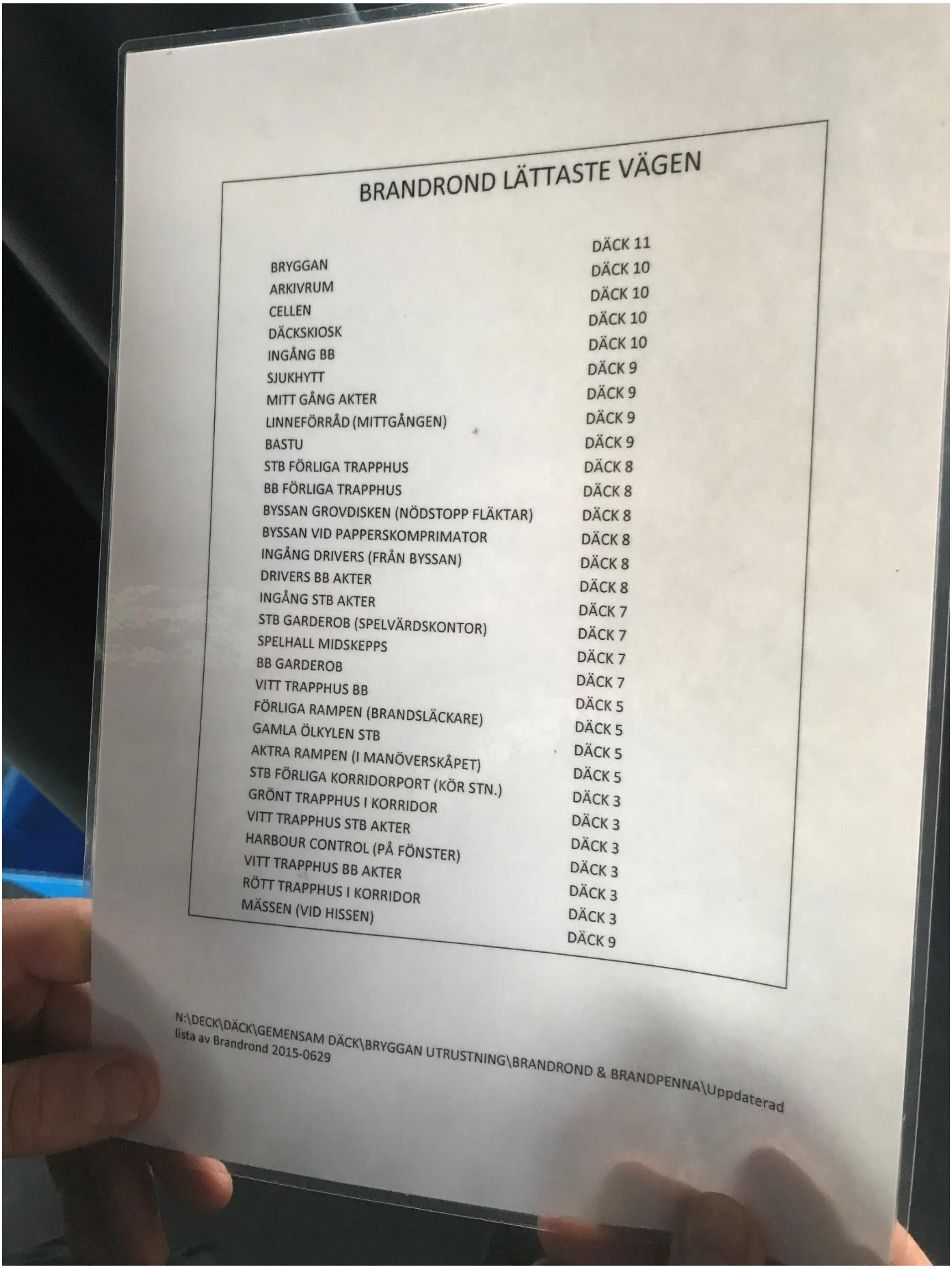
SMM-0172 Fire and Security Patrols at Sea

SOLASII-2 - Construction: Fire Protection, Fire Detection and Fire Extinction > Regulation 7 - Detection and Alarm.
Danish Regulation Notice B Kapitel II-2 Section B Regulation 8.

Fire and Security Patrol at Sea (Stena Flavia)				Stena Line
Version No. 1	Revision Date. 2018-06-01	Document ID. SOM-1002	Page. 3	



Annex A8 - Fire patrol checkpoints Stena Jutlandica



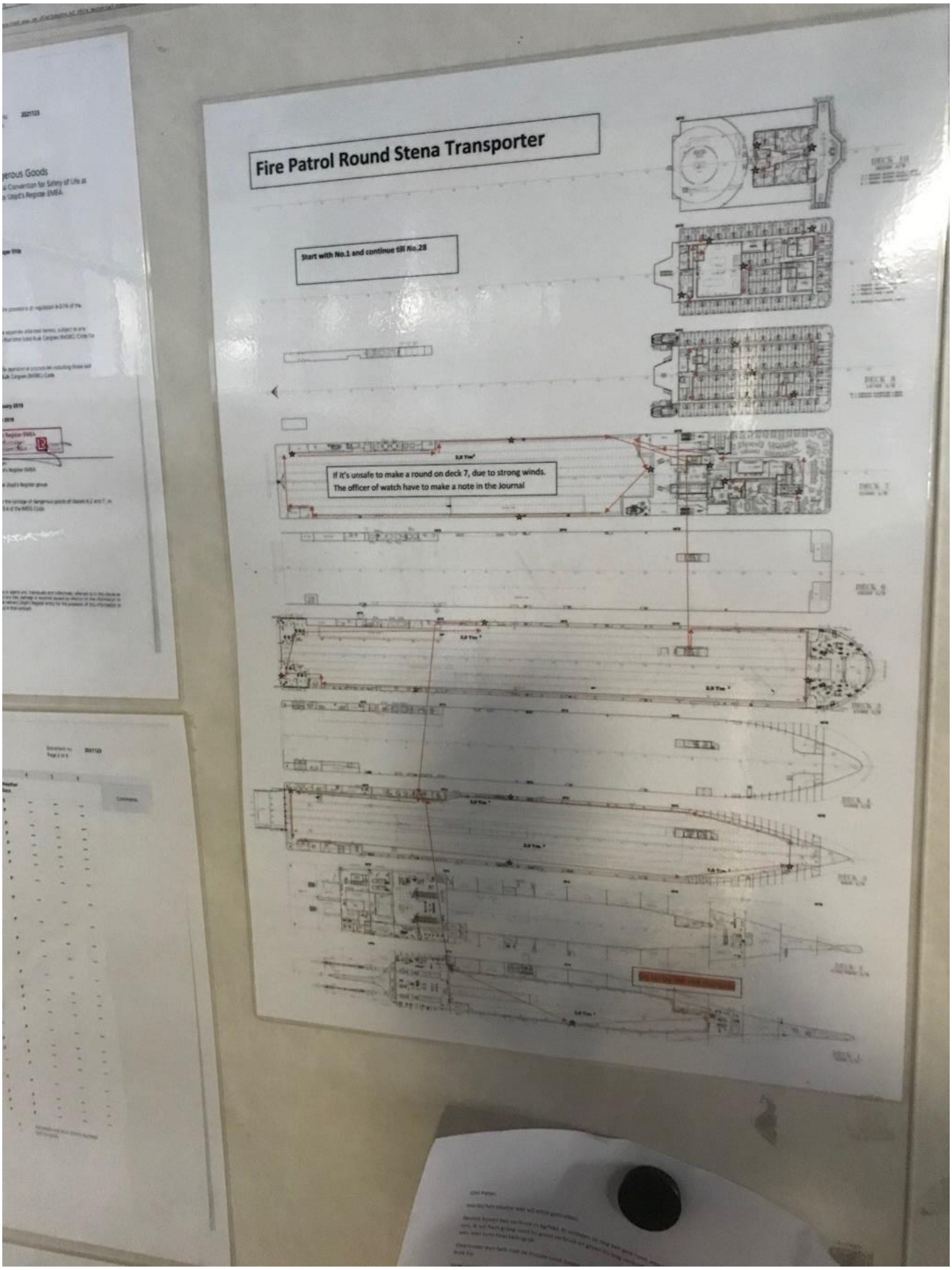
BRANDROND LÄTTASTE VÄGEN

BRYGGAN	DÄCK 11
ARKIVRUM	DÄCK 10
CELLEN	DÄCK 10
DÄCKSKIOSK	DÄCK 10
INGÅNG BB	DÄCK 10
SJUKHYTT	DÄCK 9
MITT GÅNG AKTER	DÄCK 9
LINNEFÖRRÅD (MITTGÅNGEN)	DÄCK 9
BASTU	DÄCK 9
STB FÖRLIGA TRAPPHUS	DÄCK 8
BB FÖRLIGA TRAPPHUS	DÄCK 8
BYSSAN GROVDISKEN (NÖDSTOPP FLÄKTAR)	DÄCK 8
BYSSAN VID PAPPERSKOMPRIMATOR	DÄCK 8
INGÅNG DRIVERS (FRÅN BYSSAN)	DÄCK 8
DRIVERS BB AKTER	DÄCK 8
INGÅNG STB AKTER	DÄCK 7
STB GARDEROB (SPELVÄRDSKONTOR)	DÄCK 7
SPELHALL MIDSKEPPS	DÄCK 7
BB GARDEROB	DÄCK 7
VITT TRAPPHUS BB	DÄCK 5
FÖRLIGA RAMPEN (BRANDSLÄCKARE)	DÄCK 5
GAMLA ÖLKYLEN STB	DÄCK 5
AKTRA RAMPEN (I MANÖVERSKÅPET)	DÄCK 5
STB FÖRLIGA KORRIDORPORT (KÖR STN.)	DÄCK 3
GRÖNT TRAPPHUS I KORRIDOR	DÄCK 3
VITT TRAPPHUS STB AKTER	DÄCK 3
HARBOUR CONTROL (PÅ FÖNSTER)	DÄCK 3
VITT TRAPPHUS BB AKTER	DÄCK 3
RÖTT TRAPPHUS I KORRIDOR	DÄCK 3
MÄSSEN (VID HISSEN)	DÄCK 9

N:\DECK\DÄCK\GEMENSAM DÄCK\BRYGGAN UTRUSTNING\BRANDROND & BRANDPENNA\Uppdaterad lista av Brandrond 2015-0629

"Däck 3" and "Däck 5" are ro-ro decks.

Annex A9 – Fire patrol Stena Hollandica and Stena Transporter



Fire Patrol Stena Hollandica

- Starting of the Fire Patrol at the Bridge at every full Hour.
- Turn right to PS-corridor on deck 12 and go aft wards to **F.P.P. 1**, which is in the forward AC-Room 1. Go via PS-corridor to **F.P.P. 2**, which is in the Crew Pantry, then via PS-corridor to the Blue Staircase and cross over to SB side. Go aft wards via SB-corridor to **F.P.P. 3**, which is inside the forward door of AC-Room 3.
- Go aft wards via SB-corridor to **F.P.P. 4**, inside the Sauna Area. From there aft wards to the Orange Staircase down to deck 11. Via PS-corridor forward, turn left and go forward till the Blue Staircase to **F.P.P. 5**. Take the Centre-corridor to **F.P.P. 6**, which is near the Linen Locker at the Yellow Staircase. Go to SB-corridor and forward to **F.P.P. 7**, which is inside the Purple Staircase.
- Go down to deck 10 to **F.P.P. 8** and via SB-corridor aft wards to the Yellow Staircase for **F.P.P. 9**. Then via the Centre-corridor aft wards to the Blue Staircase for **F.P.P. 10**. Take the PS-corridor aft wards to **F.P.P. 11**, which is inside the Emergency Generator Room, then go via the outside stairs on SB-side down to deck 9 for **F.P.P. 12**, which is aft of the Outside Bar.
- Go inside the Living Area to **F.P.P. 13**, which is outside the Internet Room. Then go forward via SB-side to **F.P.P. 14**, which is in front of the Riva Bar. Cross over to PS and go via the Metropolitan Restaurant aft wards to **F.P.P. 15**, which is in front of the forward Scullery Room. Via PS-corridor into the Galley and cross over to SB-side for **F.P.P. 16**, which is inside the Handling Area. Go aft wards and then inwards the Galley again for **F.P.P. 17**, which is near the Galley Office. Then aft wards to **F.P.P. 18**, which is located near the aft Scullery Room. Go down the White Staircase for **F.P.P. 19** and via the Embarkation Deck forward to **F.P.P. 20**, which is inside the Red Staircase. Go onto the centre of Cardeck 7 and aft wards to **F.P.P. 21**, which is inside the Brown Staircase. Go forward again via the centre and cross over to the Blue Staircase for **F.P.P. 22**. Via the SB Embarkation Deck forward to **F.P.P. 23**, which is in the Green Staircase. Go forward to **F.P.P. 24**, which is in the Purple Staircase.
- Go down to deck 5 and forward to **F.P.P. 25** near SB Paint Locker. Via the centre go all the way aft wards to the Orange Staircase for **F.P.P. 26** near Fire Locker 4. Go outside again and aft wards to **F.P.P. 27**, which is at SB mooring deck. Then down to deck 3 and across to **F.P.P. 28**, which is PS of the stern ramp. Then forward via the centre to **F.P.P. 29**, which is PS of the bow door. Go aft wards to the Yellow Staircase and downstairs to deck 2 for **F.P.P. 30**, which is near the entrance to the Equipment Room.
- Go down to Cardeck 1 and then aft wards to **F.P.P. 31**, which is near the entrance to the Workshop. Then forward to the elevator to go up the way up to deck 12.
- At deck 12 go forward via SB-corridor to Crew Day Room and Officers Mess Room to **F.P.P. 32** in the Yellow Staircase. Cross over to PS-corridor and forward back to the Bridge.

Annex A10 – FIRESAFE II

10.2.3 → *Increased frequency of fire patrols*

The fire patrol frequency is a key parameter for fire prevention and early detection. The fire patrol can smell smoke at very early stage of fire development, see and smell fuel spills before ignition, hear the noise from malfunctioning mechanical equipment and disturb unsolicited activities.

Efficient fire patrols are required as per SOLAS II-2/7.8 and SOLAS II-2/20.4.3.1 on passenger ships carrying more than 36 passengers and specifically in special category spaces. However, it is unclear what is meant by "efficient" with regards to the frequency of fire patrols and it can have different meanings for different ships. The size of the ship for example has a large impact on the cost versus frequency of fire patrols since it may imply hiring of additional crew.

This RCO implies increasing the frequency of fire patrols from every 60 minutes to every 30 minutes.

Table 22: Probabilities of early detection failure by the fire patrol due to *too low frequency of fire patrols*

Patrol frequency	P(Early detection by the fire patrol)	P(Early detection failure by the fire patrol)
120 min	16.5%	83.5%
90 min	21.5%	78.5%
60 min (reference)	30%	70%

Another approach could have been to have more frequent fire patrols only when the fire ignition probability is the highest. For example, there could be several fire patrols e.g. every 30 minutes for the first 1,5 hour of journey and then only fire patrols every 120 minutes (for long journeys). The fire ignition probability is greater in ro-ro spaces just after leaving port since the vehicles are still warm and faults initiated while driving can develop into fire with some delay. However, this RCM implies fire patrols in ro-ro spaces every 30 minutes throughout the whole journey.

The RCM only considers increased frequency of fire patrols and not more efficient fire patrols with regard to quality. Quality aspects include equipment, communication means, accessibility, motivation, experience and training.

10.2.3.1 Benefits

If present at the fire location, fire patrols have higher potential of early detection of incipient fires or potential fires compared to automatic fire detection systems. Increased patrol frequency implies increased probability of a patrol passing a fire during the incipient phase. Further, many fires are caused due to electrical problems, which normally means overheated components or cables and a long incipient phase with smouldering fire, which sometimes produce too little smoke to be detected by the smoke detectors.

Also, fire patrols can give extra attention to known fire risks, such as refrigeration units, or to spaces without efficient fire detection system, such as weather decks and spaces close to ventilation outlets in open and closed ro-ro spaces.

10.2.3.2 Critical aspects

More scheduled fire patrols do not automatically mean that the fire patrols will take place as planned. High workload and low motivation can be reasons for skipped or shortened fire patrols. Control systems with checkpoints can be supportive.

Efficient fire patrols are dependent on both frequency of fire patrols and quality of the inspection. Quality aspects include suitable equipment, e.g. gas sniffer or IR-camera, low motivation, e.g. tired, stressed and unfocused. Further, other aspects are accessibility problems, lack of training and experience, and communication flaws.

10.2.3.3 Interdependencies of RCMs

RCMs related to the quality aspects of fire patrols will have greater impact if the frequency of fire patrols is increased. In addition, the overall efficiency of fire patrols affects all RCMs related to the efficiency of automatic fire detection systems. However, fire patrols and fire detection systems are most often complementary, and regardless of the efficiency of either technical systems or fire patrols it is also positive with redundancy.

10.4.3 *Increased frequency of fire patrols*

The fire patrols shall be conducted immediately after departure and then every 30 minutes. No change in the quality of the fire patrol is investigated.

Current fire patrol is conducted based on a pre-determined route and controlled by checkpoint tool. Fire patrol shall be dressed in long sleeved clothing preferably in non-melting material and proper shoes so that if a fire is found they are likely to act on it fast with good probability of success. Patrol carry VHF radio, flashlight, a hand held heat camera and the checkpoint pen.

RCO XX – Fire Rounds

This RCO explores the effect of more frequent interval of fire patrol. What effect could be seen if rounds would be every 30-60-120 mins-5 hours? Cost wise this could only be evaluated based on reference ship situation today. Normal for the reference ships is 60 minutes interval. No cost for less frequent patrols will be given. No changes in quality is accounted.

Total cost Stena Flavia

€ 0

Included items: Calling out one additional AB if increase to 30 mins.

Ship owner's comments: Fire round after departure and after that every 60 mins is reference case. Maintenance could be affected if calling extra watchman for more frequent rounds but in the long run there might be a cost attached to this.

Total cost Stena Gothica

€ 60 000 yearly cost

Included items: Employing one additional AB if increase to 30 mins

Ship owner's comments: Average frequency of rounds is every 60-90 mins as reference case, if increase to 30 mins, one additional AB would be needed. This vessel has sufficient accommodation for one extra crew.

Total cost Stena Superfast

€ 60 000 yearly cost

Included items: Calling out one additional AB if increase to 30 mins

Ship owner's comments: Rounds every 60 mins + more frequent at the start and end.
Increase to 30 mins one additional AB would be needed. This is to cover both fire patrol and maintenance activities normally carried out on passage. This vessel has sufficient accommodation for one extra crew.

ANNEX B

Annexes related to Action 6-B Quick manual fire confirmation, localization and assessment

Annex B1 - Visual confirmation of location on cargo deck - examples

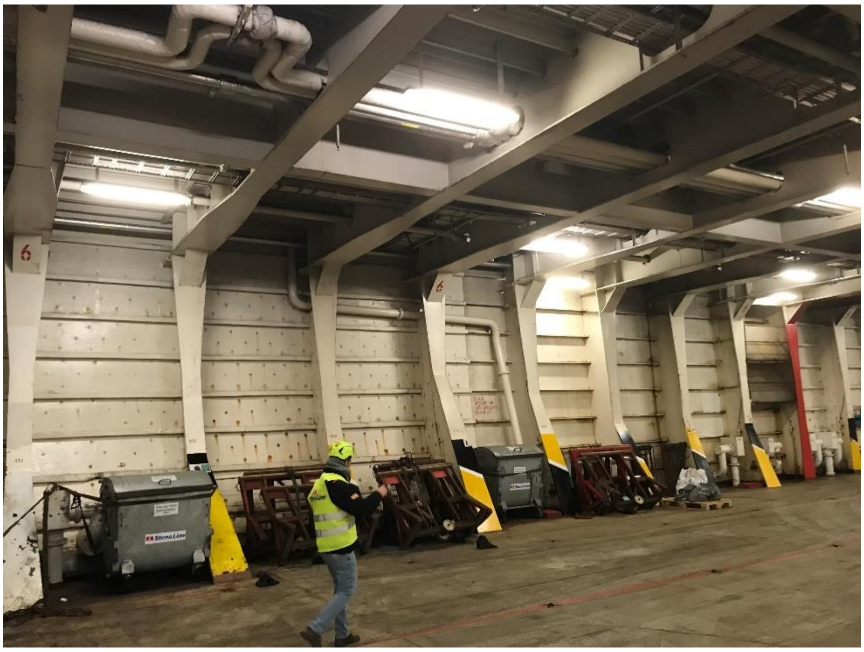


Figure 1. Drencher zone and frame numbering on bulkhead on Stena Flavia.

Figure 2. Drencher zone and frame numbering on bulkhead on Stena Jutlandica.

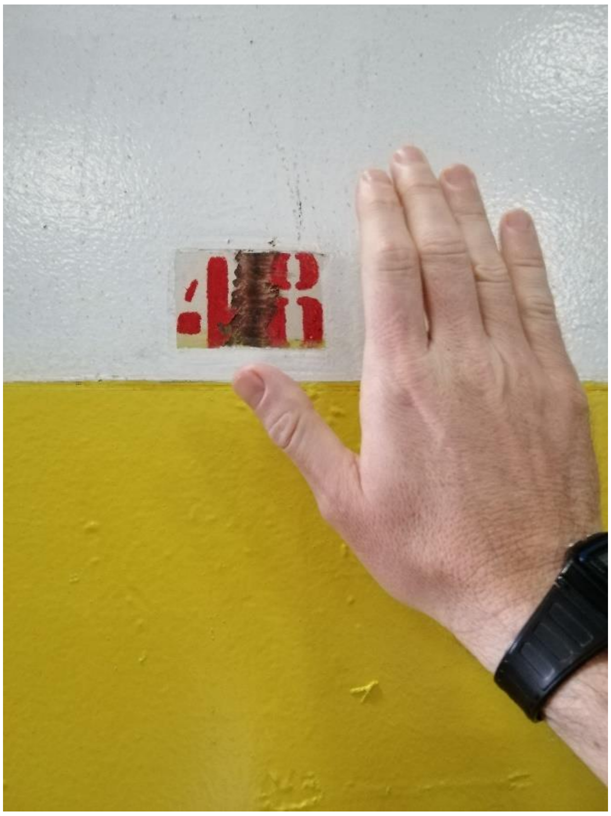


Figure 3. Frame marking on Napoles.

Figure 4. Frame and drencher zone marking on Napoles

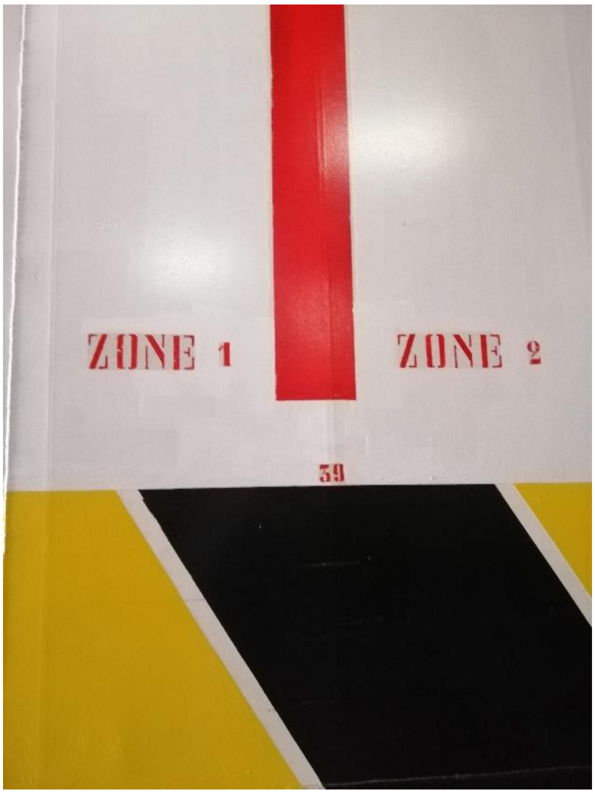


Figure 5. Drencher zone marking on Napoles.

Annex B2 - Sample procedures at Stena

Fire Alarms - Responsibility & Procedure				
Version No. 1	Revision Date. 2018-11-19	Document ID. SOM-1334	Page. 1	

SOM chapter: **7**

Validity: Stena Britannica

Fire Alarms
Every Fire alarm shall be physically investigated by a responsible person and confirmed as a false alarm before being reset.

The main fire alarm panel is on the bridge with a slave in the ECR and light pillar alarms throughout the ER. Whenever a Fire alarm is activated it shows the location of the fire and sounds an audible alarm at each panel and display, if the panel alarm is not muted from the bridge or ECR within 2 minutes the General Alarm will sound throughout the ship.

Responsibility
It shall remain the responsibility of the **Deck OOW** (Officer Of the Watch) for all fire alarms, regardless of the location of the alarm. A fire alarm will take precedent over any other part of the ship's routine operation including loading or discharging cargo and passengers.
The Deck OOW cannot delegate this task to any other person other than another Deck Officer.

Procedure
If the bridge is manned the OOW will mute the alarm and then request a crew member to investigate. Once the alarm is confirmed as false the alarm can be reset.

When the ship is in port the duty Deck Officer may be elsewhere. It is then up to the engine room OOW to inform him that there is a fire alarm and give him the location of the fire.

The Deck OOW will then request a responsible person to investigate the fire. Engine OOW can mute the alarm while the alarm is investigated.

If the General Alarm sounds when passengers are aboard – after the alarm has been investigated a PA will be made in the passenger accommodation only to inform them of a false alarm.

Comment: On some vessels, in addition to above, alarm is sounded in Master and Chief Engineer cabins after 60 seconds.

Fire (Stena Germanica)				
Version No. 1	Revision Date. 2017-06-10	Document ID. DS-0911	Page. 1	

Fire

Actions:	Checked:
1. Send out AB/Security on watch to investigate area. And inform Engine department.	
2. If fire broke out press the General alarm button.	
3. Advise the AB/security to make an initial effort if possible.	
4. If the fire is on car deck, switch of power supply to plugin hoses and start sprinkler from Valmet system.	
5. Note the time and position.	
6. Contact Stena Security Center.	
7. Manoeuvring the ship to suit the circumstances	
8. Inform passengers and other crewmembers (continuous info).	
9. Switch on all deck light and if necessary car deck lights.	
10. Light up NUC if necessary.	
11. Send out a DSC call regarding fire.	

Fire (Stena Vinga)				Stena Line
Version No. 1	Revision Date. 2019-01-29	Document ID. SOM-1607	Page. 1	

SOM chapter: 8 **SMM reference:**

Validity: Stena Vinga

Immediate and simultaneous actions

On board the ship

1. Stop the alarm by pressing the "ALARM MUTE" button on the port side fire alarm panel.

2. Check the alarm code to find out which sensor in which zone has been triggered. Look at the drawing next to the panel to find out where in the ship the concerned sensor is situated.

3. Send a deckhand from the watch, equipped with a walkie-talkie, to the alarm area to check the area.

4. Contact and consult the ECR.

5. If a fire has broken out, set the alarm selector in position 1 or 2, depending on who the alarm is intended for. Then press the green "GENERAL ALARM" button to activate the sounding of the alarm. Inform the ECR.

   Position 1: "ALL SHIP"
   Position 2: "CREW ONLY"

6. Check which fans and dampers need to be closed and close these. (MER UTFÖRLIGT BEHÖVS, FÅR TA REDA PÅ)

7. Close the fire doors by pressing the green button "Fire Doors Closed" on the aft port side bridge panel. Make an announcement in the PA before doing so.

8. Make sure that the watertight doors are shut.

9. Manoeuvre the ship considering the art of the fire - e.g. find a lee, stop, steer downwind or into the wind.

10. The safety team starts operating. The crew is mustered at the appropriate muster points, and waits on further orders from the bridge.

11. The Chief Engineer will be in command of the fire group when fighting the fire.

12. Radio stations are manned.

13. Inform passengers and crew (continuous information).

14. ISB signal to be displayed/given.

15. Switch on all deck lights.
16. Make a proper estimate of time and position (e.g. enter the position as a way-point in the GPS)

8. Fire on Vehicle Decks (Stena Nordica)				Stena Line
Version No. 1	Revision Date. 2018-08-14	Document ID. DS-1130	Page. 1	

INITIAL ACTIONS - WHEN -FIRE OR SMOKE IS CONFIRMED				
SOUND FIRE/CREW ALARM				
CLOSE APPROPRIATE VENTILATION SYSTEMS, FIRE DAMPERS AND FIRE DOORS				
VERIFY THAT FIRE PUMPS ARE RUNNING				
MAN DRENCHER STATION/ACTIVATE DRENCHERS*				
IF SERIOUS, CONSIDER TO ACTIVATE GENERAL ALARM				
SUBSEQUENT ACTIONS/CONSIDERATIONS				
SEE DS FIRE – GENERAL ACTIONS				
ACTIONS - FIRE IN PORT		ACTIONS - FIRE AT SEA		
INFORM THE LOCAL FIRE BRIGADE IMMEDIATELY		CONTACT JRCC		
VERIFY NO VICTIMS OR MISSING CREWMEMBERS		VERIFY NO VICTIMS OR MISSING CREWMEMBERS		
EVACUATE PASSENGERS AND NON-ESSENTIAL PERSONNEL		CONSIDER DESIRABILITY OF COURSE ALTERATION		
INFORM HARBOUR AUTHORITIES				
SHIP SPECIFIC CONSIDERATIONS/ ACTIONS				
INFORM MASTER		INVESTIGATE, SEND RR TEAM, COMMUNICATE VIA RADIO, CONFIRM FIRE EXISTS		
MANOEUVRE SHIP'S BOW TO WIND/SEA AND REDUCE SPEED, 4 STEERING MOTORS		IDENTIFY CARGO, LOCATE AND TACKLE THE FIRE ASAP. D/G CARGO PLAN + FIRE SCHEDULE		
ESTABLISH POSITION OF FIRE AND THE NEAREST ENTRIES		DRENCHERS CAN BE ACTIVATED FROM THE DRENCHER STATION, OR EMERGENCY STATION IN ENGINE ROOM		
E.R. TO ISOLATE ALL ELECTRICAL REEFER SOCKETS ON DECK		ENSURE THE LOWER HOLD BILGE PUMP IS READY AND START IT WHEN BILGE ALARMS SOUNDS. MIND THE FREE SURFACE EFFECT AND STABILITY IF DRAINING NOT SUFFICIENT		
ALPHA TEAM SHOULD BE READY TO ENTER THE HOLD TO ESTABLISHED THAT DRENCHER SYSTEM IS WORKING, TO CONFIRM THE LOCATION AND EXTEND OF FIRE AND TO MONITOR THE WATER LEVEL FROM DRENCHER SYSTEM		IN THE EVENT OF A DRENCHER SYSTEM FAILURE, SEVERAL TEAMS WILL BE REQUIRED TO ENTER		
BOUNDARY COOLING MAY BE REQUIRED ON ABOVE DECK		INFORM COMPANY DPA AND COASTGUARD ("PAN PAN" OR "MAYDAY")		
QUICK-CLOSING VALVES ON FUEL/LUB OIL LINES TO BE SHUT DOWN IN AFFECTED AREA				

*Activation of the drencher system must be prioritized

ANNEX B3 - Fire localisation and confirmation experience from historic incidents

Fire safe I

Based on 28 accident reports, the probability of early decision was estimated to 67.9%. 4 accidents did not provide the information regarding early or late decision.

Lisco Gloria Oct 8th 2010

Instant confirmation since by coincidence an AB was on location of fire ignition as part of fire patrol at the same time as the fire alarm was activated.

Norman Atlantic Dec 28th 2014

The interviews carried out with the deck staff and in general with the staff who participated to the initial emergency phases, as well as the evidence gathered during the investigation, show that a first fire alarm was activated approximately at 04:15.

In that moment, the second mate and a seaman were on duty. In addition, considered the difficult conditions of the navigation, after departing from Igoumenitsa, the Captain decided to remain here and keep on monitoring (see. par. 4.1.8). The deck officer on the bridge, applying the correct procedure, immediately sent the seaman to the area concerned by the alarm to check its conditions, but the seaman said that in the signaled position there was only a refrigerated truck, whose combustion generator for the cooling system was working and there was no incipient fire. After about 15 minutes a fire pre-alarm was heard again and a *Fire Alarm* followed.

Thereafter, the Captain, who already was on the navigation bridge, after seeing the flames on the starboard flying bridge deck coming out of the windows (the great side openings) of deck 4, ascertained that a fire was developing on board, ordered to transmit the fire alarm (serious gravity) and to issue the *"crew call"*. In the immediately following minutes, he ordered the first mate to go on the spot (deck 4 frame 156) to check the situation and the deck officer on the navigation bridge to immediately activate the Drencher (04:30) system. Based on the evidence gathered, following our

Stena Spirit Vehicle deck fire Aug 31st 2016

At 06:38:54 an alarm was triggered in the fire alarm control panel on the bridge as a result of activation of a smoke detector in zone 110 located on the car deck No. 3 in the aft part of the ship.

The officer of the navigational watch instructed the seaman (watchman) responsible for waking up the crew before manoeuvers via the radio (UHF) to go to a car deck No. 3 and to check the situation in the aft part of the ship.

At 06:41:00 the engineer on watch from the engine control room reported to the bridge via telephone that a fire detector was activated on the car deck. In response, the watch officer informed him that a watchman had already been sent to check the car deck No. 3 at the ship's stern.

At 06:43:10 the watchman reported to the bridge by phone that he had located smoke above and around a refrigerator truck parked in front of the stern ramp (door), on the port side next to the central bulkhead (drawing No. 2 and photograph No. 4).

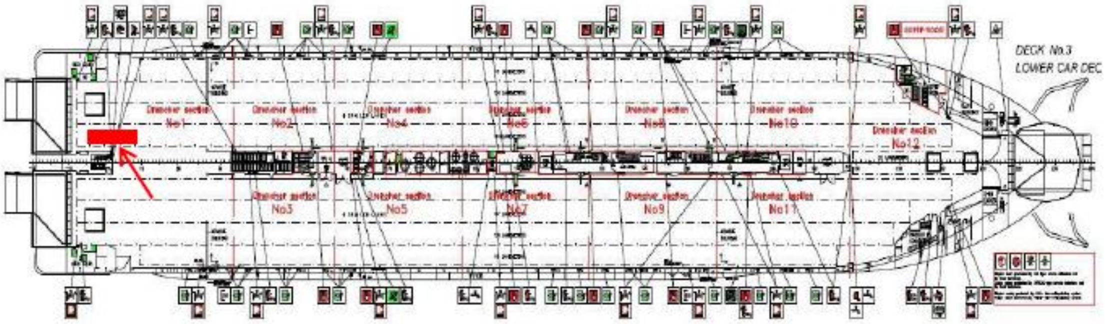


Figure 2. Refrigerator truck position on car deck no. 3

Instructed by the officer of the watch, the watchman disconnected power supply of the truck's refrigerator unit from the ship's electrical system in the distribution cubicle located on the wall of the companionway to the steering room.

Photograph No. 4. Watchman next to the refrigerator truck in smoke fumes

The officer of the watch informed the ship's electrical engineer by phone to come to the car deck to check the cause of the smoke coming from the refrigerator truck.

After passing the "GD" buoy at 06:47:34, the master came to the bridge. The chief officer and the officer of the watch reported to the master on the activation of the fire detector and presence of smoke on the car deck No. 3.

The master ordered another, detailed inspection of the area from which the smoke originated to check for any smouldering fire. Additionally, he instructed that the inspection be assisted also by the ship's safety officer who, by then, had also come to the bridge.

At 06:48:09 the officer of the watch managed to separate the fire zone 110 in the fire alarm control panel on the bridge and, thus, to deactivate the fire alarm (photograph No. 5).

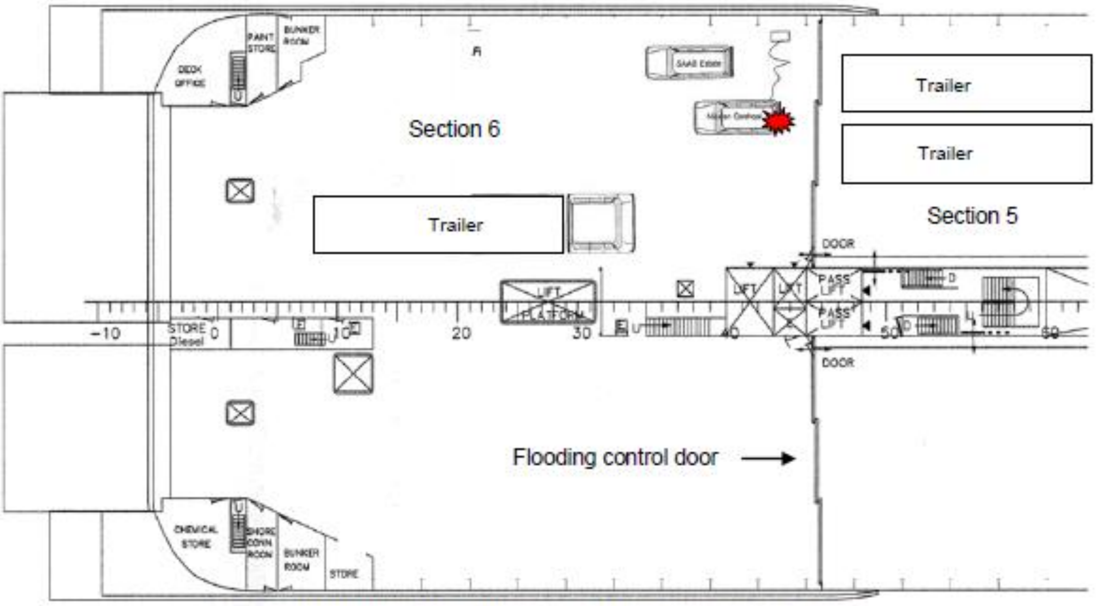
Next, the watchman present on the car deck, together with the officer of the watch on the bridge, attempted to switch on the ventilation in the cargo hold to remove the smoke that was present there. The captain stopped these activities and instructed them to wait until the ship safety officer completes the inspection ordered by the captain.

At 06:50 the electrical engineer arrived at the scene on deck no. 3 next to the refrigerator truck; the safety officer arrived soon after. Neither of them found any signs of fire, except for presence of smoke. After several minutes, they reported to the bridge that the smoke originated from the refrigerator unit, more specifically its drive's v-belts and that burnt rubber can be smelled, as well as that there was no fire hazard on the car deck.

When the crew members were checking the deck in the area of the refrigerator truck, the smoke grew thicker and flames could be seen on the image recorded by CCTV camera No. 07 which were reflected by the ceiling on the right side of the truck (photograph No. 6).

Meanwhile, the officer of the watch and the senior officer attempted to switch on the ventilation on deck no. 3. Furthermore, the officer of the watch tried for almost 2 minutes to contact the watchman in the cargo hold, but he did not succeed. The fire developed considerably and covered the entire width of the truck's roof (photograph No. 9).

Pearl of Scandinavia Nov 17th 2010



The car deck aft showing where the electric car was parked

7.7 The location of the fire and initial measures

At 05:58 on 17 November 2010, an alarm sounded due to an electrical leak caused by a current-carrying wire leaking to the ship's metal construction. A few seconds later, a smoke alarm sounded indicating a fire on deck 3. A smoke detector indicated that the fire was on the car deck in section 5 close to the flooding control door. Shortly after, numerous smoke detectors indicated fire all over the car deck. When the fire alarm first sounded, the ship was at a position 6 nm west of the peninsula of Kullen in Sweden.

A ship's assistant who was the look out on the bridge was immediately sent to the car deck to make observations. She opened a door to section 5 on the car deck and observed heavy smoke and flames. She saw a trailer on fire close to the flooding control door. At 06:00 she informed the bridge that there was a fire in a trailer on the car deck in section 5. The seat of the fire was therefore believed to be in this section in front of the flooding control door.

Shortly after the first fire alarm at 05:58, the master was called to the bridge. Immediately after the chief officer sounded the fire alarm in the crew's quarters The master arrived at the bridge at 06:03 and took over navigational command.

Position where the fire broke out Google Earth

Stena Britannica lower hold fire Jan 17th 2018

At 0239 on 17th January 2018, the Fire Alarm activated on the Bridge. The duty bridge OOW sent Able Seaman to investigate. He (fire patrol AB) quickly located the vehicle on fire and let off one fire extinguisher onto fire. He found that he could only receive Radio comm with bridge but could not transmit a clear call to bridge. So he ran up to deck 3 to get a clear radio signal to confirm the fire. NB he could have activated a manual call point but he knew the bridge was already aware of the location of the fire. He would still have needed to run up to deck 3 to make the call to the wheelhouse to give important information on the fire. Radio comms between wheelhouse and car deck 3 was poor and only one way for the whole of the emergency. It was also poor between BA Parties and BA control on deck 1. Recommend to IMPROVE RADIO COMMUNICATIONS IN THE LOWER HOLD. Note: we have since tested radios in the EMPTY lower hold and found comms very good. This issue appears to be when we have a full ship. As an interim measure, recommend more use should be made of the DECT phone system.

ANNEX C

Annexes related to Action 6-C, Efficient first response

ANNEX C1 - Extracts of first response events from incidents and accident reports

"Vessel was delayed at sailing time when a crew member reported vapour coming from a drum in a car trailer. Sailing was deferred pending investigation. The chief officer left the bridge to investigate. Engines were stopped. The driver of the vehicle was called down along with 2 artic drivers with the intention of removing the trailer from the vessel. The starboard stern door was opened and the operations manager was called. While the C/O and the driver were discussing the source of the vapour the driver removed a polythene covering and there was an immediate flare up with dense smoke. **Crew members used 2 foam extinguishers and 1 dry powder extinguisher to supress the burning contents of the drum.** The chief officer activated the drencher system for the appropriate zone. The crew were able to push the trailer off on to the linkspan ramp where the fire was completely extinguished. No one was injured and only 2 drivers were soaked by the drenchers. Passengers were kept informed throughout."

"During loading operations in Dublin, the bosun notified the loading officer that when he tried to plug in the ships connection to a fridge trailer on deck 5, the unit and plug connection started to spark. Me and the loading officer then proceeded to deck 5 upon arriving at the trailer I could immediately see embers falling onto the deck, the bosun took another look and could see visible flames through a small vent in the bottom of the unit. I immediately informed the bridge and captain of the situation, the bosun informed shoreside and requested an empty tug to attend deck 5 to take the trailer off the deck. The bridge asked if we would have to go to incident stage, I was confident that the fire was small enough to be handled by an extinguisher and asked 2nd Officer where the nearest CO2 extinguisher was, she informed me of one in the Semsafe room, which I retrieved. The fire had not grown in size but was still burning and was visible through the bottom vents (as visible in the attached pictures, where the vent is white is where the CO2 was used). **I aimed the extinguisher at the vents and used short bursts until I was happy the fire was out we then opened the cabinet of the unit and we could see the fire was clearly out.** The tug driver was then waved in to take it off the deck and to the patch ashore, we gave him the extinguisher in case it reignited on the way down the ramp."

"During changing over fridge unit from diesel to plug in, fridge started finally on plug in, and after few minutes the sparks came out , and small flame occurred. **Crew member disconnected plug in immediately, and completely switched off fridge unit**."

"Seaman plugged in refrigerated trailer once it was parked on deck 5. When ships power was turned on the bosun noticed that the fridge started to spark and smoke. **The power was immediately turned off and the cable unplugged. A fire extinguisher was quickly collected in case it was required**. Smoking reduced. The patch was called to remove the trailer. Email sent to Dublin Port to inform them of the situation."

"Box Van WB 3897N requested a 5 Pin 440 V plug in off the Shore loader in HH and the Bosun was told this on deck 5. The box van was sent to deck 5 where he in fact needed a 3 pin 230 V plug in. The Bosun gave the Driver the ships cable for this and the driver plugged the unit in himself to ships supply. The Bosun advised him to remain at his vehicle for at least 10 mins to ensure his reefer was working correctly. The driver did this, told the Bosun he was satisfied and then went into the accommodation.

A few mins later one of the loading crew noticed the vans reefer unit smoking and alerted the Bosun and bridge. The unit was immediately switched off and disconnected from the ships supply. The driver was also located and returned to the car deck. The unit continued to smoke, and as the loading was completed the box van could not be discharged ashore. Still smoking and the unit hot, **2 x fire Ext were discharged into the reefer.** The smoking then stopped and there was a marked reduction in the reefers temperature. With the unit cooled and not smoking, car deck fans were started to clear the small amount of smoke and fumes. A fire watch was the maintained on the unit for the rest of the passage, which passed without incident."

"While loading trailers in LRP one of the ABs noticed smoke and flames coming from under one of the trailers. He raised the Alarm and with the help of the other ABs on deck they managed to put the fire out before it could take hold **using a foam extinguisher from the blue stairwell DK3**."

"In the early hours of 17th January there was a major fire in the lower hold of the vessel which burnt for nearly 6 hours and caused major damage to trucks and the vessel. The lower hold, deck 1, is below the main vehicle deck, deck 3, and the vehicle access is down two ramps, one at each end, from deck 3 which have hydraulically operated locking covers. At 02.39 a fire alarm sounded on the bridge and as per usual practice the watchman was sent down to investigate. The fire head involved was on the starboard side of 1 deck just forward of midships. The watchman found a fire behind the cab of an articulated lorry in front of the fifth wheel. He raised the alarm and **attacked the fire with fire extinguishers, but he was unable to extinguish it.** At 02.52 the drencher system was activated, the Mate Master (night master) was called to the bridge and the crew were called to emergency stations (Working party red). The Mate Master left for the fire station as he is in charge of the working party and the Master came to the bridge and took over on the bridge. EMPROC was activated, the Coast Guard and the port of Harwich, our destination, were informed and the ship proceeded in to port at maximum speed. A crew member was sent to unlock the lids to the lower hold in case the fire damaged the locks thus preventing the lids being opened later. At 03.00 two men in B.A. sets entered the lower hold but were unable to extinguish the fire. At 03.13 the first fire team left the lower hold and were replaced by another team. The general emergency alarm was sounded and the ship went to general emergency. Announcements were made for all passengers to proceed to the muster stations on deck 9. Further announcement to the passengers were made throughout the emergency to keep the them informed. At 03.21 the second team exited believing the fire to be out however on further entry it was discovered that the fire had re-ignited and until the vessel docked further teams entered fighting the fire with the drenchers were running continuously. 19 breathing apparatus air bottles were used. The vessel arrived in Harwich at 05.14 and on arrival the Essex Fire Brigade took control of the situation .On arrival in Harwich the foot passengers were discharged via the gangway. Most vehicles and drivers were discharged immediately. First the freight vehicles on 3 deck and then the freight vehicles on 5 deck with the passenger cars on 3 deck last. The drivers of the trucks in the lower hold remained on board in the Taste Restaurant as we needed them with their keys to help us get the trucks out. The trailers which were mainly on deck 7 were discharged later. The fire brigade entered the space and on their instruction we opened the ramp covers at around 06.30. The fire brigade informed us that the fire had finally been extinguished at 08.45. Once the smoke had cleared drivers were called down one by one so that their trucks could be unlocked and in some cases driven off. Of the 22 articulated trucks in the lower hold 9 appeared to be undamaged and 13 were damaged or completely burnt out. The lower hold was severely damaged, however the rest of the ship was unaffected. The last damaged vehicle, which was probably the one where the fire started, was removed at 17.30. The fire brigade eventually had 10 fire engines in attendance and they classified it as a major incident. The cause of the fire is not known at present."

“Small fire on reefer unit road train. When berthing at Kiel between 0905-0915 local time we get a fire push bottom indication from car deck 4 aft area. The engine and some of the deck crew observed the fire and immediately **start the firefighting with portable extinguishers and firehoses**. At 0915 hours the fire was extinguished.
After the fire was put out, 2 crewmembers with smoke diving apparatus watched the unit until it was unloaded from the vessel. 3 crewmembers were sent to hospital in Kiel for medical check, due to inhalation of smoke.“

“A small fire occurred under need the battery station of a truck driver unit. Couse is unknown. Watchman discovered smoke coming out of the unit, later saw flames coming out. Did not hesitate called the bridge for alarm and **extinguished the fire with a powder extinguisher**. Fire was directly out and under control. Chief Officer woke up the driver to get the keys if needed. Went to the scene and confirmed the fire is out.”

“The watchman, not being able to contact the bridge via radio (VHF), started to **extinguish the fire with a 50 kg transportable powder extinguisher**. He attempted to put out the fire approaching from the rear, left side of the truck, but powder jets did not reach the area of the flames.”

ANNEX C2 - Typical fire patrol outfit in practice

Figure 1. Example of a fire patrol outfit on a RoPax vessel.

Figure 2. Example of a fire patrol outfit on a RoPax vessel.

ANNEX C3-Example of WIFI coverage of cargo decks of a RoPax vessel

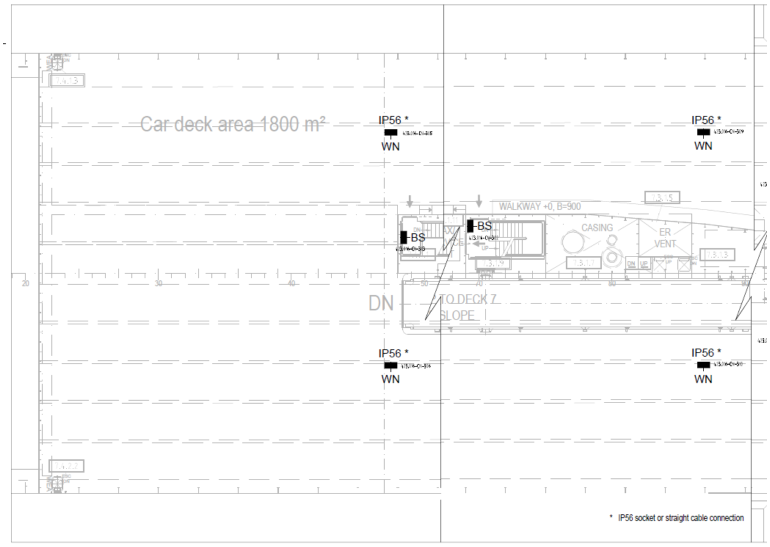


Figure 1. WIFI Access points ("WN"), car deck 7

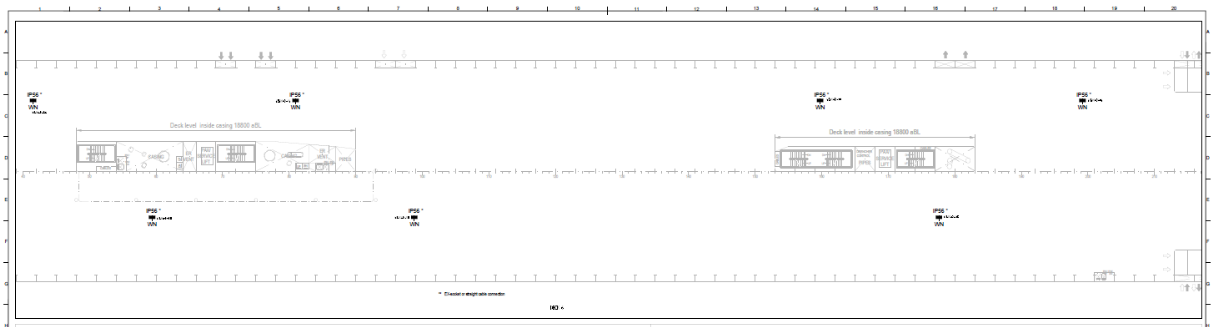


Figure 2. WIFI Access points ("WN"), cargo deck 5

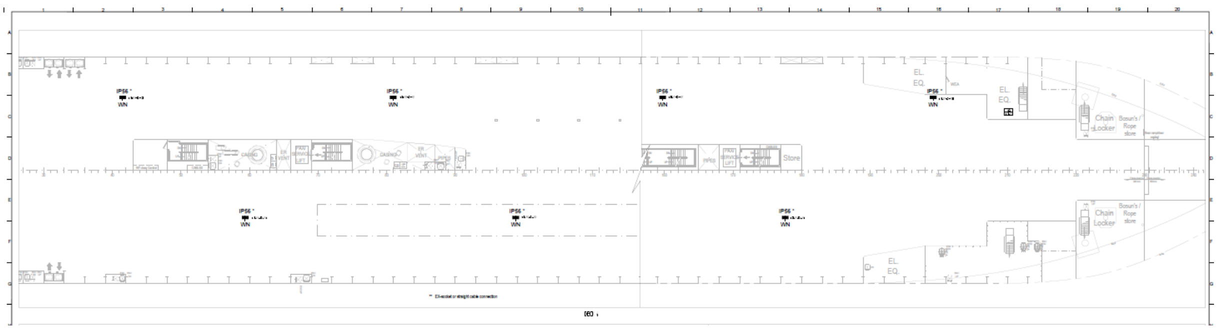


Figure 3. WIFI Access points ("WN"), cargo deck 3

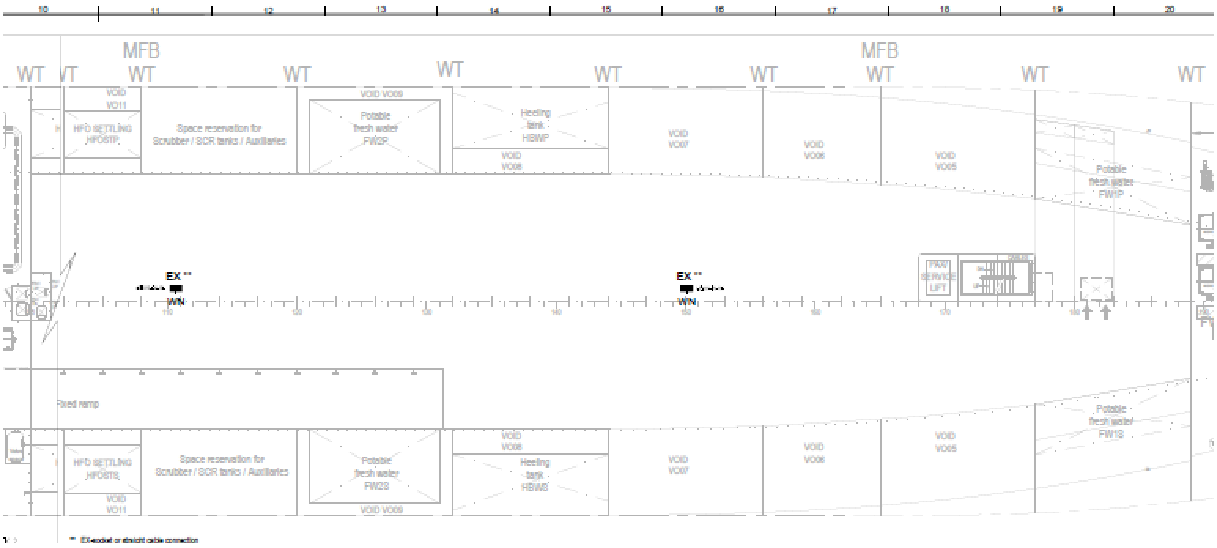


Figure 4. WIFI Access points ("WN"), cargo deck 1

ANNEX D

Annexes related to Action 6-D, Effective and efficient manual firefighting

ANNEX D1- Sample fire team RoPax

Fire muster list M/V Stena Flavia

Signal	Constant ringing with bells.

Supernumerary personnel

Supernumerary personnel are marked in italicized
Other personnel muster on bridge at captain's disposal.

The Chief Officer is responsibility for the maintenance of all FFE.

Bridge group (CH 4)		**Engine group (CH 4)**	
Muster station	**Bridge**	**Muster station**	**Engine control room**
100 Captain	**Senior leader of all operations**	**200 Chief eng.**	**Senior leader in engine room.**
(101 Chief off.)	**on board.**	**(201 2nd eng.)**	
102 2nd off. **(103 3rd off.)**	**External radio communication**	**202 3rd eng.** **(200 Chief eng.)**	**At chief engineer's disposal.** **Pumps** **Quick-closing valves.** **Emergency stops for electric equipment.**
103 3rd off. **(100 Cap)**	**At captain's disposal** **Ventilation** **Fire doors and dampers** **WT doors Fire Alarm** **Fire control plan** **Internal communication** **Announcement to passengers**	*203 3rd eng.* *222 motorman* *211 fitter* *205 electrician*	*At chief engineers disposal* *At chief engineers disposal* *At chief engineers disposal* *At chief engineers disposal*
114 AB	**At captain's disposal.**		
300 Purser	*At captain's disposal*		
118 AB	*At captain's disposal*		
119 AB	*At captain's disposal*		
120 AB	*At captain's disposal*		

Fire leader group (CH 4) (CH 5)			
Fire outside engine-room		**Fire in engine-room**	
101 Chief off. **(201 2nd eng.)**	**Muster on scene of fire.** **Fire fighting leader.** **Coordinates efforts and extinguishing with 2nd engineer.**	**201 2nd eng.** **(101 Chief off.)**	**Muster on scene of fire.** **Fire fighting leader.** **Coordinates effort and extin-guishing with chief officer.**
201 2nd eng.	**Muster on fire station no. 3**	**101 Chief off.**	**Muster on fire station no. 3**

Firefighting group (CH 5)

Muster station	Fire station 3, deck 7, or according to order via loudspeaker system. Bring necessary equipment.		
Fire fighting team		**Smoke diver team**	
111 AB + 112 AB	**Assist Smoke divers.**	**221 Motorman**	**Smoke diver**
	Bring personal smoke diver equipment.	**113 AB**	**Smoke diver**
	Rig hoses.	*212 fitter* *117 AB*	*Fire leader's disposal* *Fire leader's disposal*
	Begin extinction/cooling according to order.		
	Preparing of extra air bottles for later use.		

Fire in engine room

If the fire is considered impossible to extinguish, the CO_2 is released according to instructions.
When the CO_2- alarm sounds, the entire engine crew musters outside CO_2- release room, fire station 2.

Guiding group (CH 4)

Muster station		**Hall deck 5 at reception**
305 Cook **(115 AB)**	**WT**	**Leader of guiding group** **Leading passengers away from dangerous areas.**
115 AB **116 AB** **311 Stew**		**Assist cook** **Assist cook** **Assist cook**
306-325		*Cook's disposal*

DANISH MARITIME AUTHORITY APPROVED
in accordance with letter: 23.05.2016
DMA Case No.: 2016010027
Name: Michael Langkow

This document has been processed electronically and it is therefore valid without any signature.

Muster list - Skåne			
Version No. 1	Revision Date. 2020-03-01	Document ID. SOM-2141	Page. 1

Stena Line

SOM chapter: 7.1

SMM reference: SMM-0243

Validity: Skåne

Assembly stations:
Deck 7 Port Side – Lifeboat recess
Deck 7 SB Side – Lifeboat recess

Muster list M/S SKÅNE

To find your safety no, consult the appendix to this muster list
All group leaders shall carry walkie-talkie

GENERAL EMERGENCY SIGNAL: ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▬
SEVEN OR MORE SHORT BLASTS FOLLOWED BY ONE LONG BLAST ON SHIPS WHISTLE OR SIREN. THIS SIGNAL WILL BE REPEATED ON THE SHIPS ALARM SOUNDER
ALL PERSONS WILL PROCEED TO THEIR INCIDENT / EMERGENCY STATION AS LISTED BELOW
ABANDON SHIP SIGNAL: THE ORDER TO ABANDON SHIP WILL BE GIVEN VERBALLY BY THE MASTER OR OFFICER IN CHARGE OVER P/A
MANOVERBOARD SIGNAL: MANOVERBOARD SIGNAL WILL BE GIVEN VERBALLY BY THE OFFICER IN CHARGE OVER P/A. 'ASSIGNED PERSONNEL PROCEED TO MANOVERBOARD STATIONS'

BRIDGE TEAM Station: Bridge (Back up stn, Aft Bridge)	SAFETY TEAM 1 Fire station 4 (D 10) Fire fighting & Flooding Damage Control	SAFETY TEAM 2 Fire station 5 (D3) Fire fighting- & Flooding Damage Control	EVACUATION TEAM 1 Station 1 Reception	EVACUATION TEAM 2 Station 2 Conference room deck 10	EVACUATION TEAM 3 Station 3 Reception	LSA TEAM Station: Assembly station
101 Overall Command 201 Fire Chief **(note 3)** 301 I/C. Evacuation leader 103 External communication GMDSS **(note 1)** 320 Communicator 102 LSA leader **(note 2)**	104 Team leader 113 Dep. Team leader 114 Fire Fighter 115 Fire Fighter 116 Fire Fighter	203 Team leader 212 Dep. Team leader 213 Fire Fighter 214 Fire Fighter 112 Fire Fighter	311 Team leader 312 Dep.Team leader 315 Assists	313 Team leader 314 Dep.Team leader 317 Assists	316 Team leader 318 Dep.Team leader 319 Assists	111 Team leader 117 Assists
CONTROLROOM (Back up stn. Aft bridge) 204 EOW 211 Assists 202 Assists/Dep. Fire Chief	119 Assist 120 Assists	215 Fire Fighter 216 Assists 217 Assists	320 Assists 324 Assists Evacuates deck 9 forward of the reception and deck 8	322 Assists 325 Assists Evacuates cabins on deck 10	321 Assists 323 Assists 326 Assists Evacuates cabins on deck 9	118 Assists Make ready lifesaving equipment, muster of passengers, hand out life jackets and blankets, seeing that they are suitably clad and have donned their lifejacket correctly
	Back up Fire Stations 1, 2 and 3 are manned after order from the Fire Chief		EVACUATION TEAMS ARE ALSO FIRST AID TEAM			

1. 2nd Officer '103' is responsible for closing of watertight doors, fire doors, valves, scuppers, sidescuttles and other similar openings in the ship, this task may be delegated.
2. Chief Officer '102' is to ensure that life-saving appliances are maintained in good condition and are ready for immediate use.
3. Chief Engineer '201' is to ensure that fire-fighting equipment and fire appliances are maintained in good condition and are ready for immediate use.
4. The members of the evacuation teams are to warn the passengers, assembling passengers at the muster stations, keeping order in the passageways and on the stairways and generally controlling the movements of the passengers.

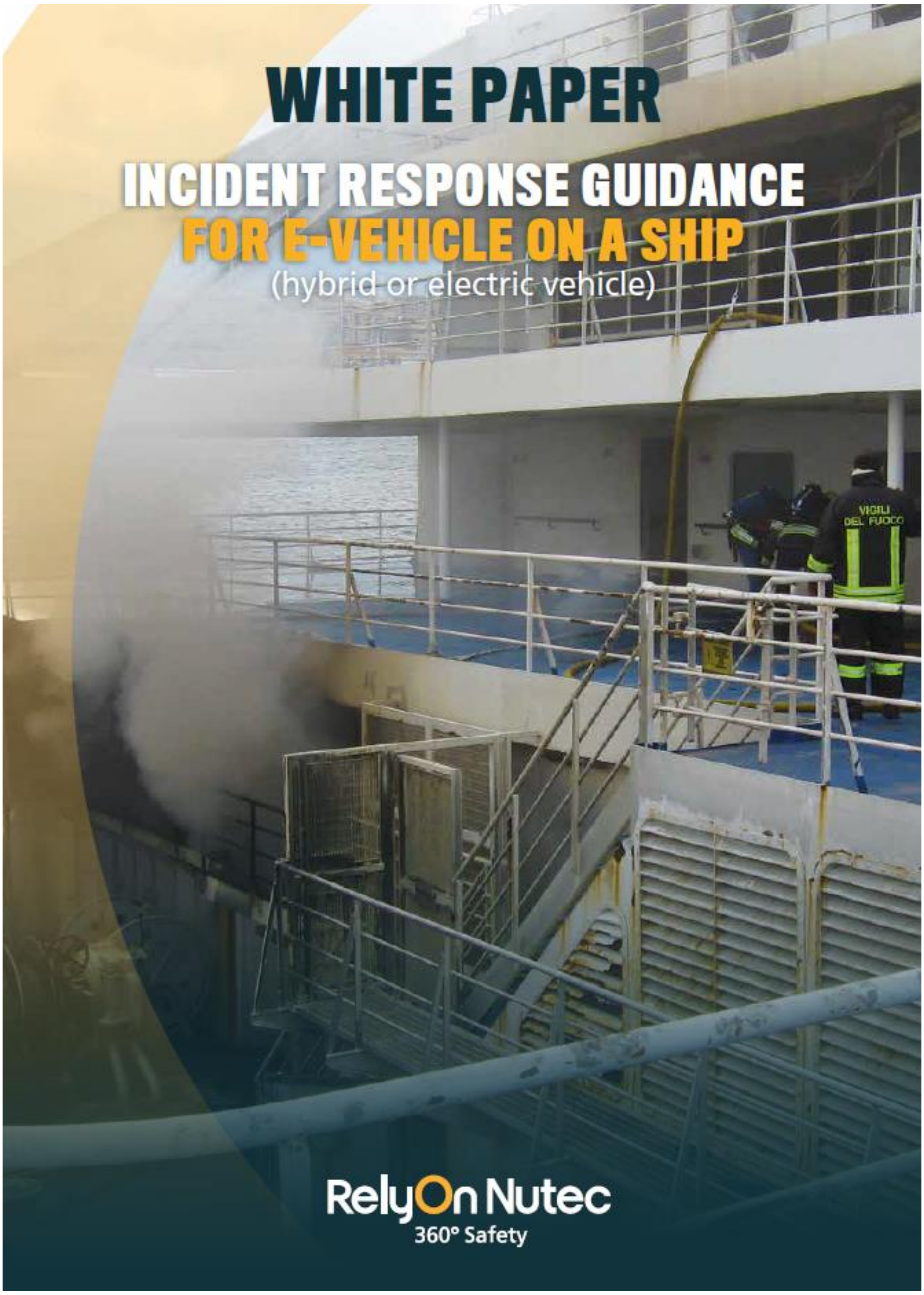
ABANDON SHIP

LIFEBOAT PORT	LIFEBOAT SB	RESCUEBOAT PORT	RESCUEBOAT SB	MES STATION PORT	MES STATION SB
102 Boat leader. Brings SART and VHF-radio 112 Dep. Boat leader 202 Engine attendant 204 Assists 212 Assists	101 Boat leader. Brings SART and VHF-radio 111 Dep. Boat leader 203 Engine attendant 201 Assists 211 Assists	104 Boat leader 114 Dep. Boat leader	103 Boat leader 115 Dep. Boat leader	116 Team leader 214 Dep.Team leader 312 Assists 314 Assists 316 Assists 318 Assists 301 Assists	113 Team leader 213 Dep.Team leader 311 Assists 313 Assists 315 Assists 317 Assists 319 Assists
320 Assists 118 Assists 120 Assists 216 Assists	117 Assists 215 Assists 119 Assists 217 Assists			322 Assists 324 Assists 326 Assists	321 Assists 323 Assists 325 Assists

MAN OVERBORD
Rescueboat port or sb is manned by

Deck Officer off duty (Survival suit)
AB on watch (Survival suit)
AB on watch (Survival suit)
Remaining deck crew prepares both rescue boats

ANNEX D2 - RelyNutec paper



ANNEX D3 - STCW Code Table A-VI/1-2 Specification of minimum standard of competence in fire prevention and fire fighting

Table A-VI/1-2 Specification of minimum standard of competence in fire prevention and fire fighting

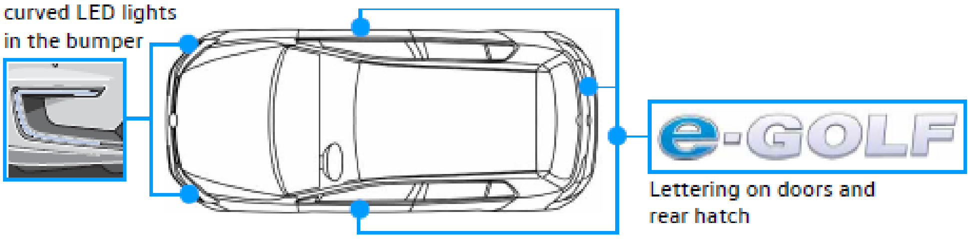
Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Minimize the risk of fire and maintain a state of readiness to respond to emergency situations involving fire	Shipboard fire-fighting organization Location of fire-fighting appliances and emergency escape routes The elements of fire and explosion (the fire triangle) Types and sources of ignition Flammable materials, fire hazards and spread of fire The need for constant vigilance Actions to be taken on board ship Fire and smoke detection and automatic alarm systems Classification of fire and applicable extinguishing agents	Assessment of evidence obtained from approved instruction or attendance at an approved course	Initial actions on becoming aware of an emergency conform with accepted practices and procedures Action taken on identifying muster signals is appropriate to the indicated emergency and complies with established procedures
Fight and extinguish fires	Fire-fighting equipment and its location on board Instruction in: .1 fixed installations .2 fire-fighter's outfits .3 personal equipment .4 fire-fighting appliances and equipment .5 fire-fighting methods .6 fire-fighting agents .7 fire-fighting procedures .8 use of breathing apparatus for fighting fires and effecting rescues	Assessment of evidence obtained from approved instruction or during attendance at an approved course, including practical demonstration in spaces which provide truly realistic training conditions (e.g., simulated shipboard conditions) and, whenever possible and practical, in darkness, of the ability to: .1 use various types of portable fire extinguishers .2 use self-contained breathing apparatus .3 extinguish smaller fires, e.g., electrical fires, oil fires, propane fires .4 extinguish extensive fires with water, using jet and spray nozzles .5 extinguish fires with foam, powder or any other suitable chemical agent .6 enter and pass through, with lifeline but without breathing apparatus, a compartment into which high-expansion foam has been injected .7 fight fire in smoke-filled enclosed spaces wearing self-contained breathing apparatus .8 extinguish fire with water fog or any other suitable fire-fighting agent in an accommodation room or simulated engine-room with fire and heavy smoke .9 extinguish oil fire with fog applicator and spray nozzles, dry chemical powder or foam applicators .10 effect a rescue in a smoke-filled space wearing breathing apparatus	Clothing and equipment are appropriate to the nature of the fire-fighting operations The timing and sequence of individual actions are appropriate to the prevailing circumstances and conditions Extinguishment of fire is achieved using appropriate procedures, techniques and fire-fighting agents Breathing apparatus procedures and techniques comply with accepted practices and procedures

Annex D4 – Sample Vehicle emergency cards

e-Golf 7
(from 2014)

Vehicle identification

curved LED lights in the bumper



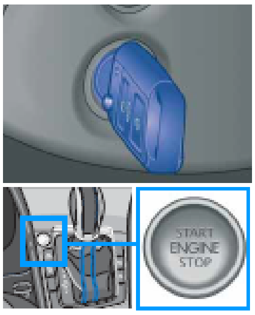
Lettering on doors and rear hatch

Prevent the vehicle from rolling

1. **Put the selector lever in the Park (P) position.**
2. **Apply the parking brake.**

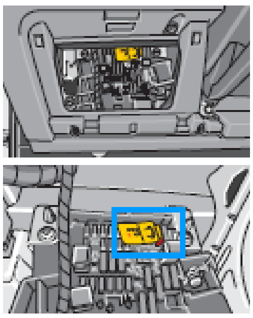
Deactivate the drive and the high-voltage system

Deactivate the drive and the high-voltage system
(when ignition and fuse carrier can be accessed from the interior)



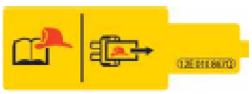
1. **Turn the ignition key to the "OFF" position and remove it or press the START/STOP button.**

Removing the ignition key deactivates passive safety systems such as airbags and belt tensioners once the airbag control unit has discharged (approx. 4 seconds).
Working on the system before the unit has discharged may damage the airbag system, causing the airbags to be triggered.



2. **Remove the storage compartment above the fuse holder on the left.**
Pull out the marked fuse.
(yellow flag)

The high-voltage system will be de-energised about 20 seconds after deactivation.
The passive safety systems such as airbags and belt tensioners are then deactivated.



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e-Golf 7 (from 2014)

Version: 03/2014, Volkswagen AG

Page 2 of 3

ANNEX E

Annexes related to Action 7-B, Efficient extinguishing system activation and inherently safe design

ANNEX E1 - How to operate a fire alarm panel on board Magnolia Seaways

The fire panels are located at the bridge, in the Engine Control Room (ECR), Safety Control Station (SCS) and in the Cargo Control Room (CCR). At some vessels only the panel at the bridge can activate the extinguishing system, the others are so called slave panels, where it is possible to acknowledge alarms.

On Magnolia the fire Detection panel at the bridge is located at the aft console.

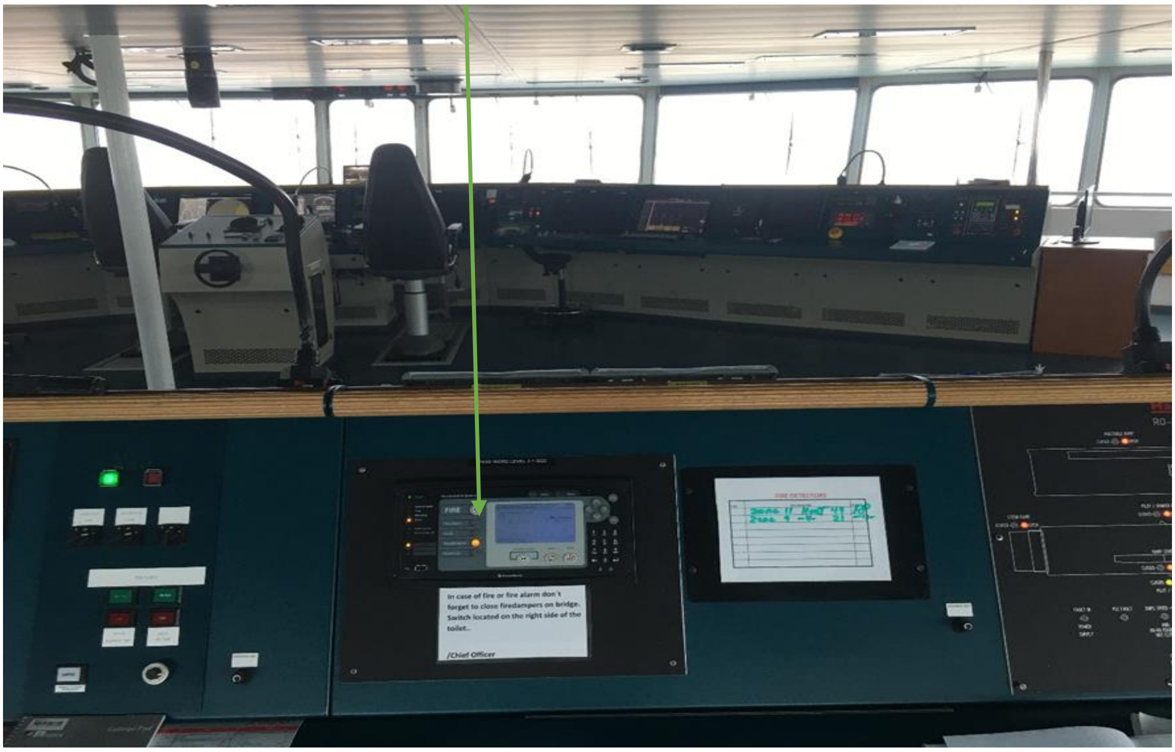


Figure 1. Magnolia Seaways- Fire detection system panel

Example of a fire alarm on the Fire Detection display.

On the Figure below is illustrated a fire alarm at 10:57 from zone 11 and that the detector is heat sensor no.63, located in upper deck Frame 129, drencher zone 4 on starboard STB side.

The fire panel system is divided into loops which makes it easier to confirm where the fire alarm is coming from. Each loop covers an area of the vessel where all smoke, heat, flame detectors and manual call points are registered.

All alarms and entry changed at the panel will be printed out on at separate printer standing aft of the consol.

Figure 2. Fire detection system panel-fire alarm

- Pin out the indication of the fire alarm.
  - Alarm activated
  - Mute alarm – Silences the internal buzzer and all external alarms
  - Following information is displayed in the Control Panel
    - Number of alarm(s)
    - First, last and current list entry
    - Zone in alarm
    - Address number of units in alarm (only for addressable loop)
    - Supplementary text (if defined in system configuration)

  - For more details press ok
    - Time of alarm
    - Date of alarm
    - Supplementary text about location of detector
  - Reset the fire alarm
    - Press reset alarm – can only be reset if alarm no longer in alarm condition
  - Reset several alarms
    - Scroll with the arrows
    - Mute and reset as above

2 Fire Alarms Menu

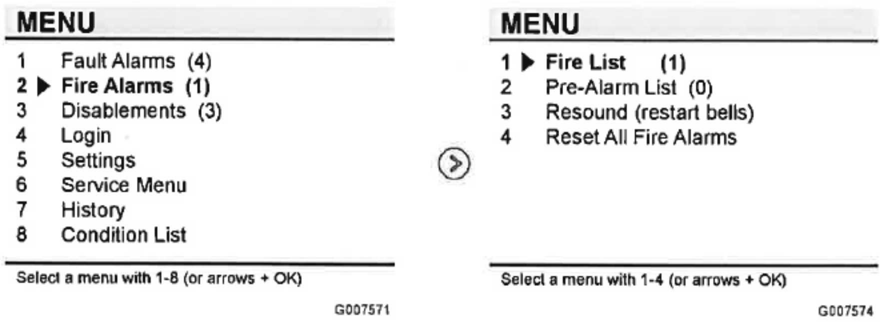


Table 3. Fire alarm menu alternatives

Alternatives	Description
1 Fire List	Shows all present Fire Alarms.
2 Pre-Alarm List	Shows all present Pre-Alarms.
3 Resound (restart bells)	If the alarm devices have been silenced by pressing Mute button, this function will restart them (if the fire alarm has not been reset).
4 Reset All Fire Alarms	The system will attempt to reset all Fire Alarms in the Fire List.

An overview of all sensors and their position can be found at the bridge. With the frame number given it is easy for the Able Seaman to find the area where the sensor has been activated as the frame numbers are marked on the ships.

Figure 3. Markings in cargo space - example

Disablements of fire alarms

It is possible to disable a loop or just a sensor. When a sensor or a loop has been disabled the panel will flash orange and indicate Disablements. It is important to remove the senor or loop from the disablements system by activating it as soon as it is ready or cleared. If there is something wrong with the senor and it cannot be removed from the disablement list, everyone who interacts with the system must be informed.

Actions to be followed in case a sensor or loop is disable for a longer time:

- The disablement should be entered in the logbook.
- Inform everyone who interacts with the system.
- All possible actions must be taken to repair or find a solution why the sensor or loop is not working.
- Extra alertness should be in that area where the sensor is out of order.

Figure 4. Fire detection system panel-disablements

When do Magnolia Seaways disable alarms

Alarms in lower deck, main deck and upper deck are disabled during discharging and loading in ports. The exhaust gas from the big trucks and cars will activate the smoke sensors therefore those alarms are disabled during port stay. As soon as the vessel is fully loaded or the stevedores having a long break, the system will be reconnected again.

The wiring of the fire system is built as two separate systems.

In case port side fire detection system is damaged in a fire, fire detectors on starboard side can still be activated.

Fault alarms

When a fault alarm activates the fire detection panel the fault code will show. In the panel fault 128 is activated. The fault code lists the cause and how an operator with knowledge of the system can solve the problem.

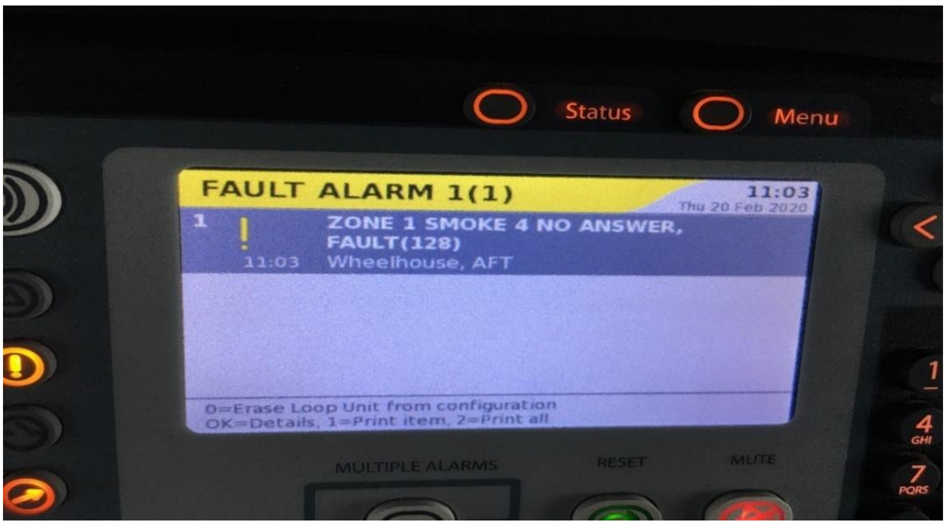
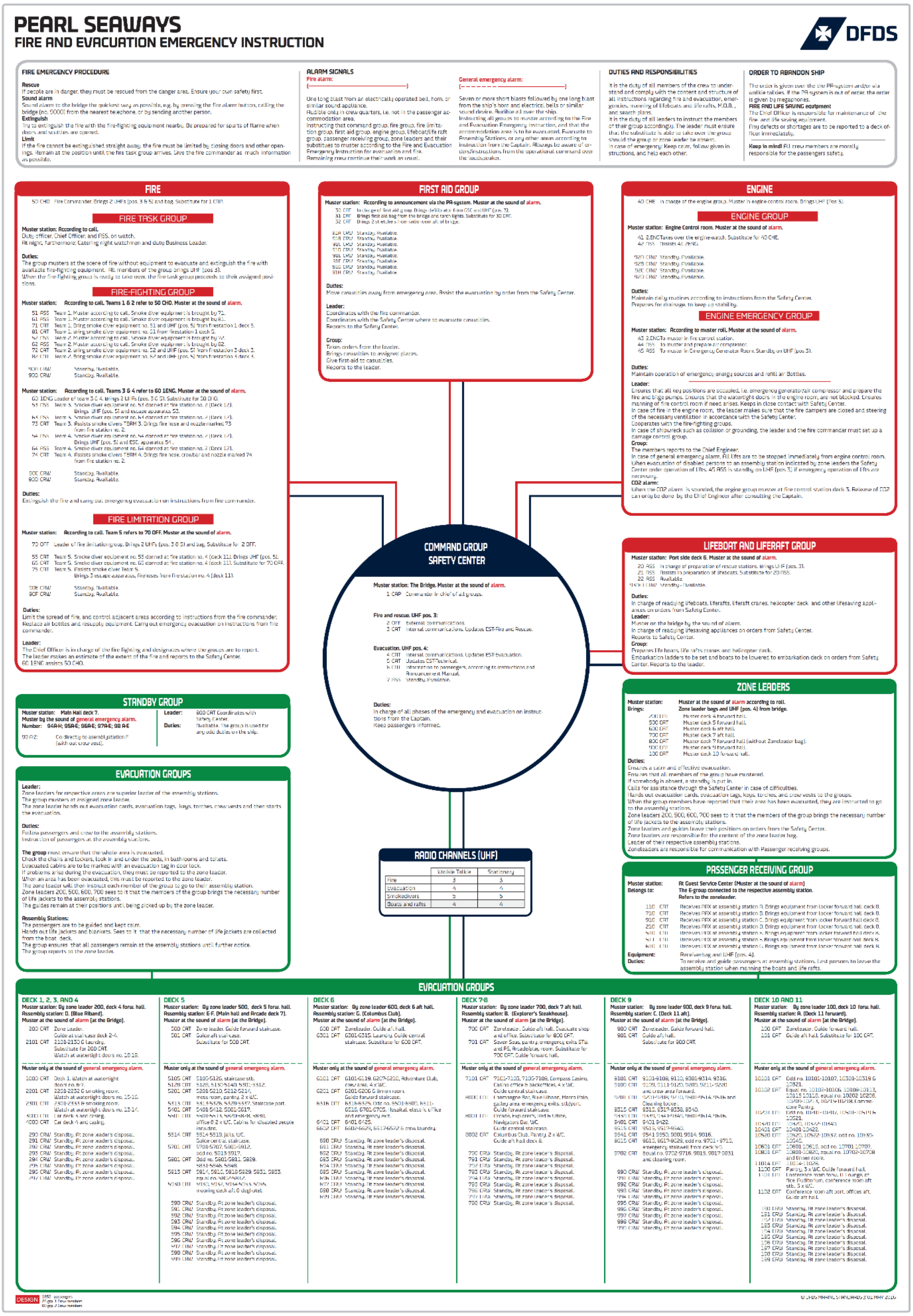


Figure 5. Fire detection system panel-fault alarm

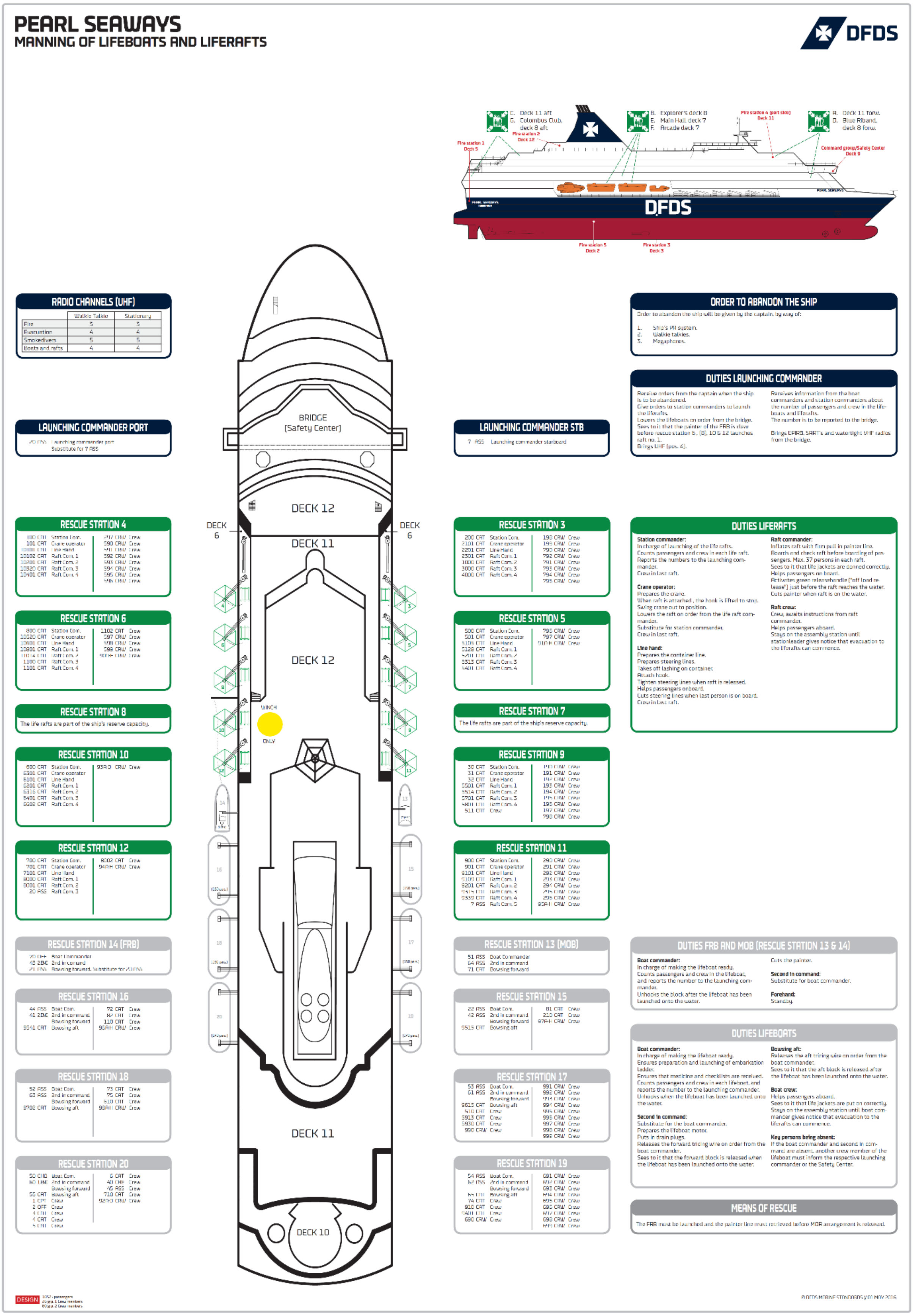
ANNEX F

Annexes related to Action 7-C, Fire resource management centre

ANNEX F1 – Pearl Seaways: Fire and evacuation emergency instruction



ANNEX F2 – Pearl Seaways: Manning of lifeboats and liferafts



ANNEX F3 Stena Jutlandica: Muster list and emergency instructions

In case of an incident/alarm, the OOW shall immediately take the following actions:

- Send the AB on watch to the area for the incident/alarm. The AB informs the bridge of what caused the alarm.
- If the situation is imminent, contact the Master immediately.
- Activate General Alarm if necessary.
- Check that water tight doors and appropriate fire doors and other openings are closed.
- Contact Engineer on watch to close fire dampers and scuppers. Stop ventilation if needed.
- Inform the Chief Engineer and the Engineer on watch of the situation.
- Follow Decision Support guidelines.

Responsibilities

- The Master has the overall responsibility of the Safety Organisation.
- The Chief Officer is responsible for the maintenance of the lifesaving-/radio equipment and the abandon ship organisation.
- The Chief Engineer is in charge of the fire fighting and is responsible for the maintenance of the firefighting equipment. He is also responsible for the readiness of the firefighting teams.
- The Chief Officer is responsible for the evacuation of passengers.
- In case of key personnel becoming disabled, deputies will replace according to the Muster List.
- Evacuation teams are responsible for locating and directing passengers to the appropriate Assembly Station.
- The task “Assist and Guide” includes making sure the passengers are suitably clothed, handing out lifevests and assist in donning them.

Communication

- The PA-system can be operated from the Bridge and Information desk. The system has an emergency power supply.
- All Teams onboard communicates via either VHF or UHF.

Evacuation

- Evacuation teams are responsible for locating and rescuing passengers/crew from cabins and public areas throughout the ship. This includes all major staircases.
  Crew cabins are also checked by the Evacuation teams.
- The Safety teams are responsible for locating and rescuing passengers/crew in dangerous areas.

3

Muster List

Crew No.	Position	Team in Safety Organisation	Duty in case of General Alarm	Duty at Abandon Ship	Life-boat	MES
			PC-level 0 = Green			
100	Master	Operational Command	In Command/ Vice Navigation	In Command		
101	Chief Officer	Operational Command	Evacuation and Stability, Damage Control (flooding) Vice in Command	I/C Abandon Ship		
102	2nd Officer	Operational Command	Navigation, Vice Evac/Stab. and Damage Control	A-crew SART&EPIRB to SB LB	FRB	
103	2nd Officer	Operational Command	Ext. Communications	Ext. Communications SART & EPIRB to PS LB Vice I/C Abandon Ship		
104	Deck Crew	LSA Team	Leader/Heli	A-crew, Launch	4	
105	Deck Crew	LSA Team	Vice Leader/Heli	A-crew, Launch	1	
106	Deck Crew	Safety Team	Smoke Diver/ Safety Duty	A-crew, Launch	3	
107	Deck Crew	Safety Team	Smoke Diver/ Safety Duty			
108	Deck Crew	Safety Team	Smoke Diver/ Safety Duty			
109	Deck Crew	Safety Team	Smoke Diver/ Safety Duty			
110	Deck Crew	LSA Team	Safety Duty/ Heli	A-crew, Launch	2	
111	Deck Crew	LSA Team	Safety Duty/ Heli	B-crew	FRB	
112	Deck Crew	Operational Command	Stand By/ Messenger/Heli	C-crew	FRB	

Crew No.	Position	Team in Safety Organisation	Duty in case of General Alarm	Duty at Abandon Ship	Life-boat	MES
200	Chief Engineer	Operational Command	I/C Fire Fighting & Damage Control			
201	1st Engineer	Safety Team	Vice Leader/ Vice I/C Fire Fighting & Damage Control			
202	Chief Electrician	Engine Control Team	Vice Leader			
203	2nd Engineer	Safety Team/ Engine Control Team	Leader/Leader			
204	2nd Engineer	Engine Control Team/ Safety Team	Leader/Leader			
205	Engine Crew	Safety Team	Smoke Diver/ Safety Duty			
206	Engine Crew	Safety Team	Smoke Diver/ Safety Duty			
207	Engine Crew	Safety Team	Smoke Diver/ Safety Duty			
208	Engine Crew	Safety Team	Smoke Diver/ Safety Duty			
209	Engine Crew	Engine Control Team/ Safety Team	Smoke Diver/ Safety Duty			
210	Engine Crew	Safety Team/ Engine Control Team	Smoke Diver/ Safety Duty			

			PC-level 1 = Brown			
316	OBS Crew	Evacuation Team Crew	Evacuate As per Instruction			
317	OBS Crew	Evacuation Team Crew	Evacuate As per Instruction			
318	OBS Crew	Evacuation Team Crew	Evacuate As per Instruction			
			PC-level 2 = Orange			
320	OBS Crew	MES Team 7	Leader	MES Leader		21
321	OBS Crew	MES Team 7	Vice Leader	Platform Leader		21

4

ANNEX F4 - Stena Flavia: Muster list and emergency instructions

Fire muster list M/V Stena Flavia

Signal	Constant ringing with bells.

Supernumerary personnel

Supernumerary personnel are marked in italicized
Other personnel muster on bridge at captain's disposal.

The Chief Officer is responsibility for the maintenance of all FFE.

Bridge group (CH 4)		**Engine group (CH 4)**	
Muster station	**Bridge**	**Muster station**	**Engine control room**
100 Captain **(101 Chief off.)**	**Senior leader of all operations on board.**	**200 Chief eng.** **(201 2nd eng.)**	**Senior leader in engine room.**
102 2nd off. **(103 3rd off.)**	**External radio communication**	**202 3rd eng.** **(200 Chief eng.)**	**At chief engineer's disposal.** **Pumps** **Quick-closing valves.** **Emergency stops for electric equipment.**
103 3rd off. **(100 Cap)**	**At captain's disposal** **Ventilation** **Fire doors and dampers** **WT doors Fire Alarm** **Fire control plan** **Internal communication** **Announcement to passengers**	*203 3rd eng.* *222 motorman* *211 fitter* *205 electrician*	*At chief engineers disposal* *At chief engineers disposal* *At chief engineers disposal* *At chief engineers disposal*
114 AB	**At captain's disposal.**		
300 Purser	*At captain's disposal*		
118 AB	*At captain's disposal*		
119 AB	*At captain's disposal*		
120 AB	*At captain's disposal*		

Fire leader group (CH 4) (CH 5)			
Fire outside engine-room		**Fire in engine-room**	
101 Chief off. **(201 2nd eng.)**	**Muster on scene of fire.** **Fire fighting leader. Coordinates efforts and extinguishing with 2nd engineer.**	**201 2nd eng.** **(101 Chief off.)**	**Muster on scene of fire.** **Fire fighting leader. Coordinates effort and extin-guishing with chief officer.**
201 2nd eng.	**Muster on fire station no. 3**	**101 Chief off.**	**Muster on fire station no. 3**

Firefighting group (CH 5)

Muster station	Fire station 3, deck 7, or according to order via loudspeaker system. Bring necessary equipment.		
Fire fighting team		**Smoke diver team**	
111 AB + 112 AB	**Assist Smoke divers.**	**221 Motorman**	**Smoke diver**
	Bring personal smoke diver equipment.	**113 AB**	**Smoke diver**
	Rig hoses.	*212 fitter* *117 AB*	*Fire leader's disposal* *Fire leader's disposal*
	Begin extinction/cooling according to order.		
	Preparing of extra air bottles for later use.		

Fire in engine room

If the fire is considered impossible to extinguish, the CO_2 is released according to instructions.
When the CO_2- alarm sounds, the entire engine crew musters outside CO_2- release room, fire station 2.

Guiding group (CH 4)

Muster station		**Hall deck 5 at reception**
305 Cook **(115 AB)**	**WT**	**Leader of guiding group** **Leading passengers away from dangerous areas.**
115 AB **116 AB** **311 Stew**		**Assist cook** **Assist cook** **Assist cook**
306-325		*Cook's disposal*

DANISH MARITIME AUTHORITY APPROVED
in accordance with letter: 23.05.2016
DMA Case No.: 2016010027
Name: Michael Langkow

DMA001.1 This document has been processed electronically and it is therefore valid without any signature.

ANNEX G

Annexes related to Action 8-A, Automatic screening and management of cargo hazards.

ANNEX G1- Stena Line rePort system

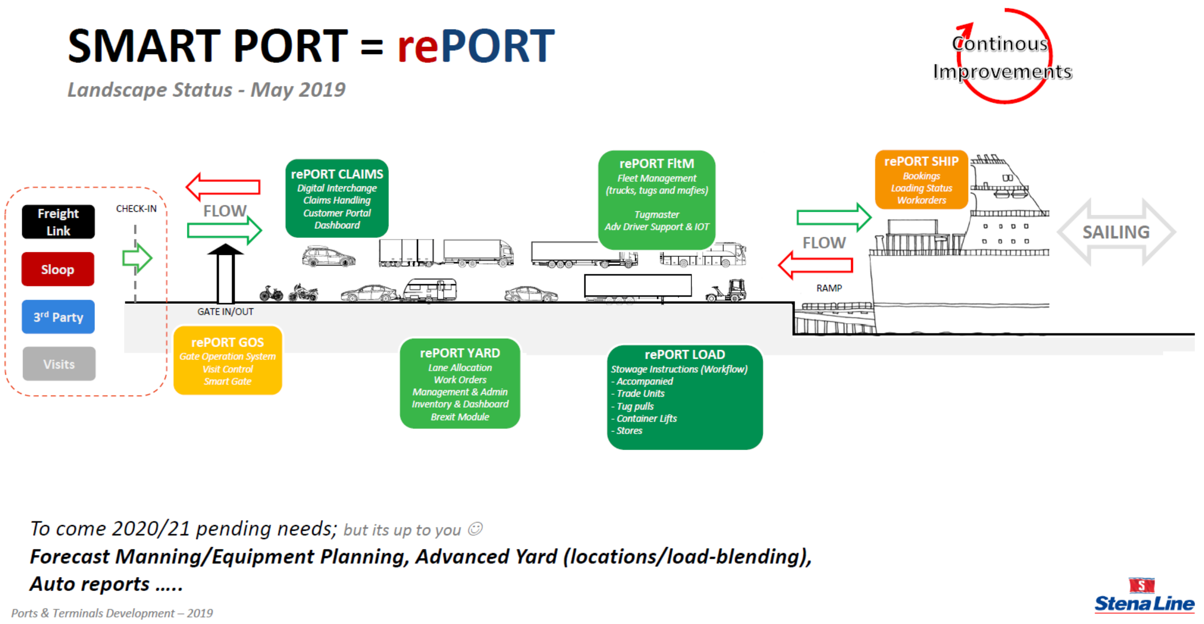


Figure 1. Overview of report system.

ANNEX G2 - Stena Line GateLAB

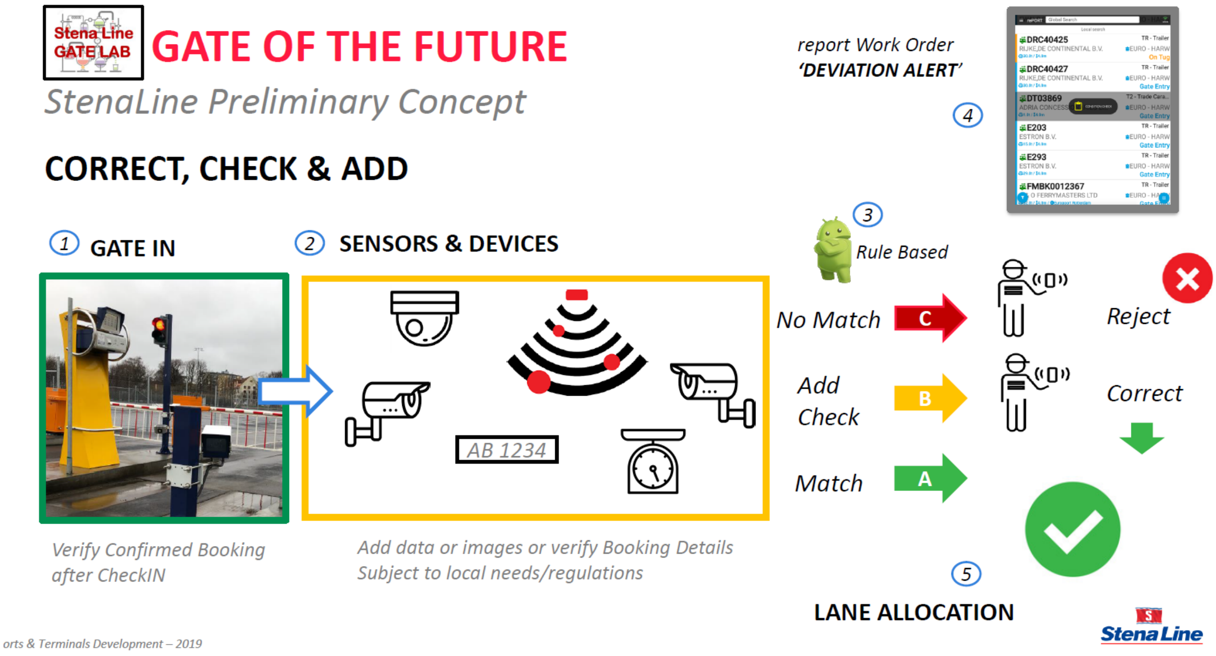


Figure 1. Overview of gate function.

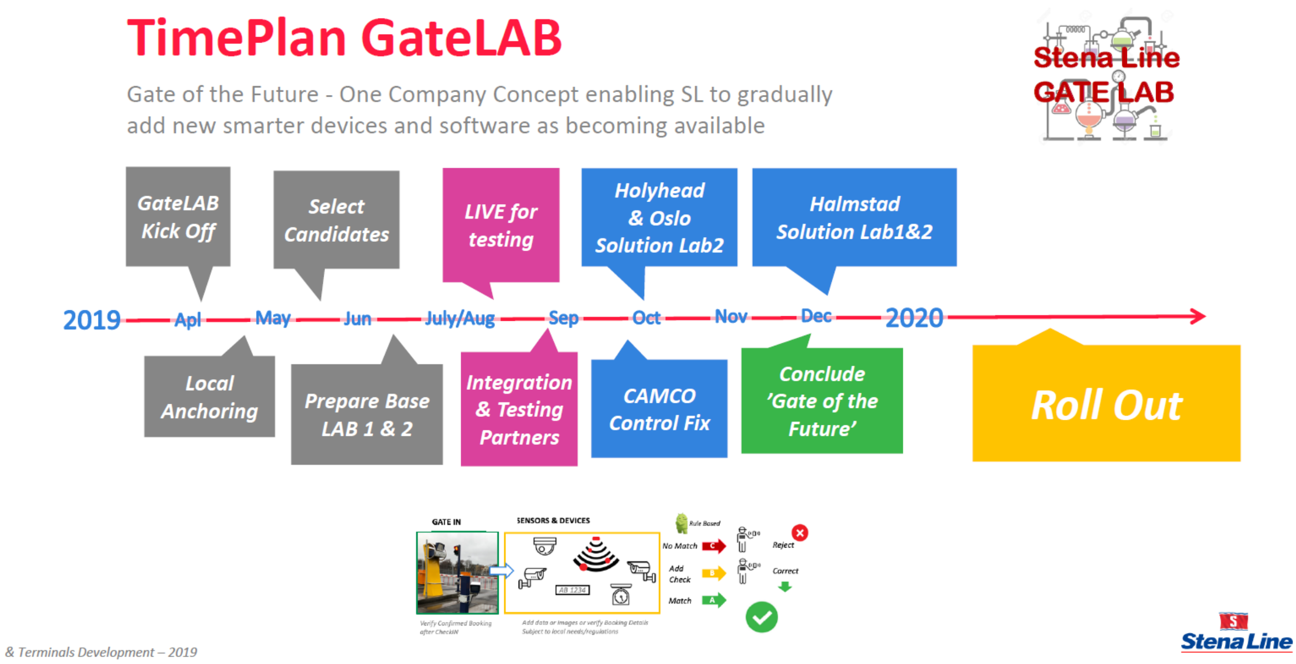


Figure 2. RePORT project timeline.

Figure 3. Karlskrona terminal filter for accompanied vehicles.

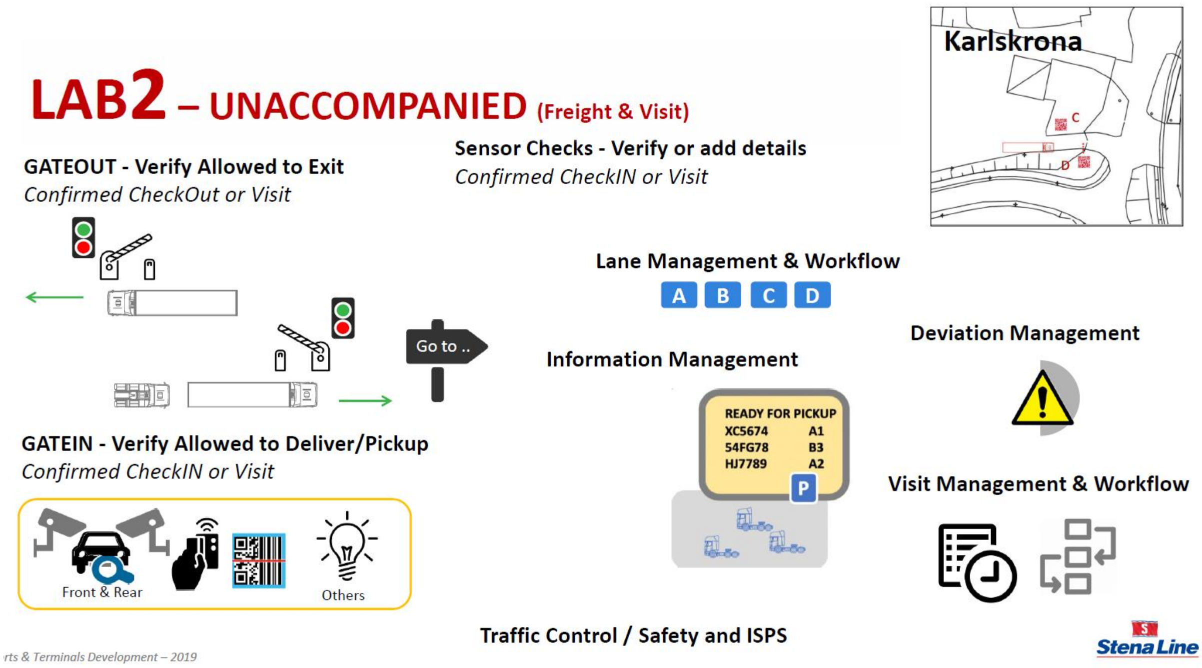


Figure 4. Karlskrona terminal filter for un-accompanied vehicles.

Figure 5. Hoek van Holland terminal gate.

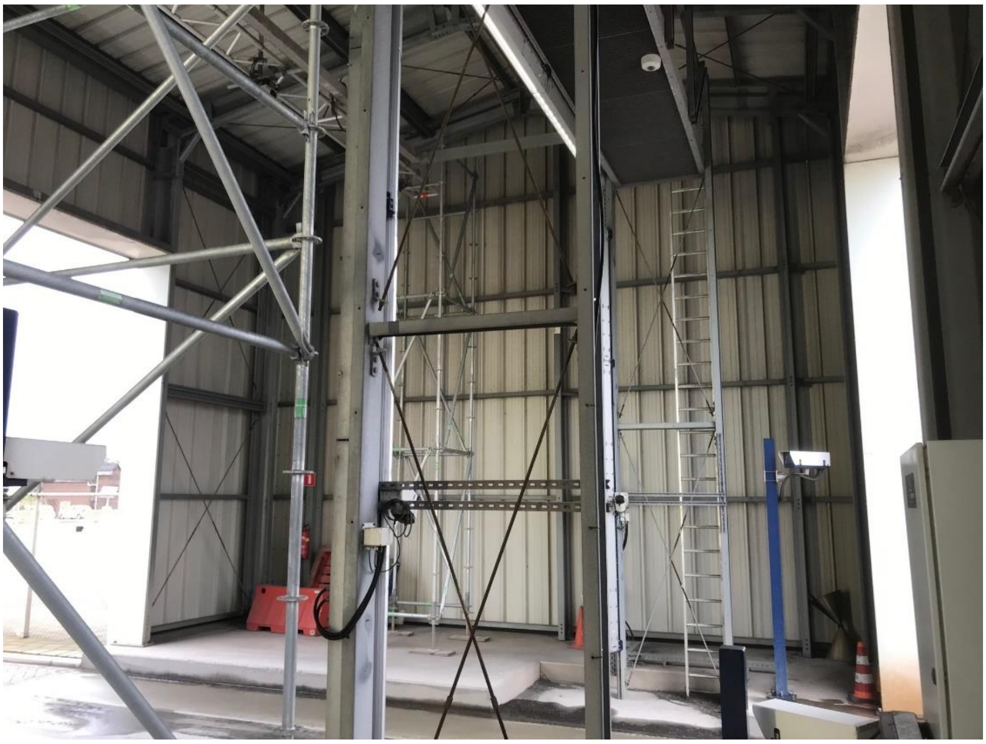


Figure 6. Hoek van Holland terminal gate.

ANNEX G3- Typical DG Cargo manifest (Stena Line)

Stena Line

Summary Hazardous Manifest

Selection: Route: Nynäshamn-Ventspils Departure Date: 2019-11-07 Departure Time: 2130

Ship: SCOTTISH VIKING Baltic Sea Regulation: N

Item: 1 Veh Reg:AA7744 T8828 VT:AR Acc LENGTH:17,0 Stowage: A Deck: O or U BOOKING NO: 63990244 STATUS: CHECKED IN

UN CODE	CLASS	SUBRISK	PACK GRP	EMS	IMDG	TYPE	FP	WASTE	NEQ	PROPER SHIPPING & TECHNICAL NAMES (as declared)	WEIGHT
1950	2.1			F-D, S-U	Y	LQ		N		AEROSOLS |Flammable, max. 1L. PCK: 30 FIBREBOARD BOXES	163

Item: 2 Veh Reg:BRP909 VT:TR Unacc LENGTH:14,0 Stowage: A Deck: O or U BOOKING NO: 63986685 STATUS: CHECKED IN

UN CODE	CLASS	SUBRISK	PACK GRP	EMS	IMDG	TYPE	FP	WASTE	NEQ	PROPER SHIPPING & TECHNICAL NAMES (as declared)	WEIGHT
3164	2.2			F-C, S-V	Y	N		N		ARTICLES, PRESSURIZED, HYDRAULIC (containing non-flammable gas)|Articles, pressurized, hydraulic. PCK: 1 FIBREBOARD BOX	3

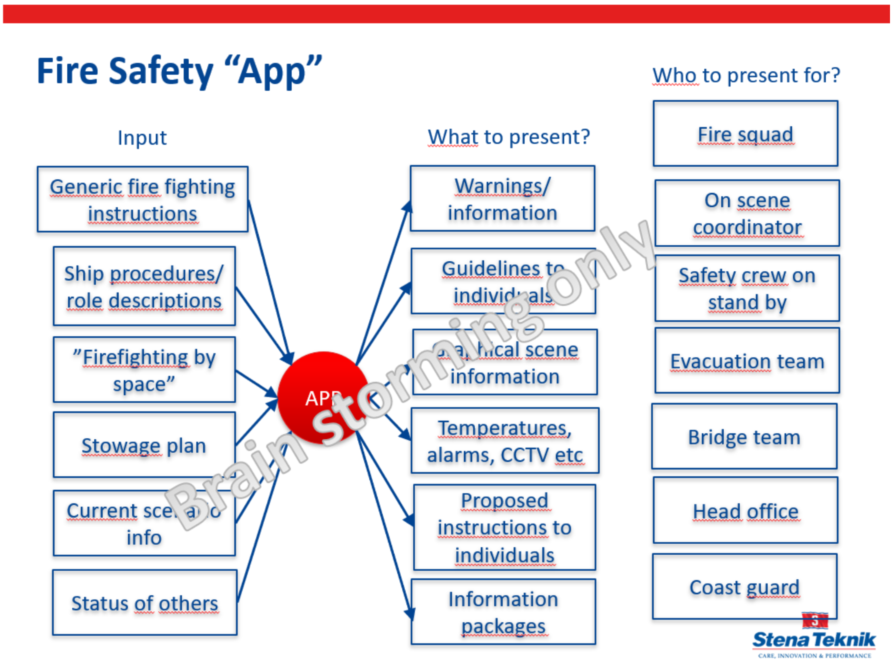
Item: 3 Veh Reg:FF4141 U6856 VT:AR Acc LENGTH:17,0 Stowage: A Deck: O or U BOOKING NO: 66230555 STATUS: CHECKED IN

UN CODE	CLASS	SUBRISK	PACK GRP	EMS	IMDG	TYPE	FP	WASTE	NEQ	PROPER SHIPPING & TECHNICAL NAMES (as declared)	WEIGHT
2735	8		III	F-A, S-B	Y	N		N		AMINES, LIQUID, CORROSIVE, N.O.S. |Amines, Packing group III. ISOPHORONEDIAMINE PCK: 89 PLASTIC DRUMS	96
2327	8		III	F-A, S-B	Y	N		N		TRIMETHYLHEXAMETHYLENEDIAMINES|| PCK: 5 METAL DRUMS	6
2735	8		III	F-A, S-B	Y	N		N		AMINES, LIQUID, CORROSIVE, N.O.S. |Amines, Packing group III. ISOPHORONEDIAMINE PCK: 10 PLASTIC DRUMS	4
3082	9	Marine Pollutant	III	F-A, S-F	Y	N		N		ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S.|| EPOXIDE RESIN PCK: 2 METAL DRUMS MARINE POLLUTANT: YES	46
2327	8		III	F-A, S-B	Y	N		N		TRIMETHYLHEXAMETHYLENEDIAMINES|| PCK: 2 METAL DRUMS	17
2735	8		III	F-A, S-B	Y	N		N		AMINES, LIQUID, CORROSIVE, N.O.S. |Amines, Packing group III. ISOPHORONEDIAMINE PCK: 39 PLASTIC DRUMS	14

ANNEX G4 - Stowaway detection system Hoek van Holland

Figure 1. Stowage lanes detection system

ANNEX G5 - Fire Safety App brainstorming



ANNEX G5 - Alphatron IR heat detection system installed on Stena Transporter

Proven solution

Several recent total losses of RoRo ships with open ro-ro spaces have stressed the need for investigating more efficient detection in open RoRo spaces and weather decks. The AlphaHeatDetectionSystem was extensively tested with different fire scenarios to challenge the system, taking into account the effects of ventilation, weather and other relevant factors. The test carried out on the Stena Scandinavica and witnessed by Class Society Bureau Veritas Marine and Offshore and RISE Fire Research AS, was concluded with positive results, reflecting the system is able to more rapidly detect heat sources compared to common smoke detectors.

Customer case Stena

Peter van de Wardt, Senior Master on the RoRo Stena Transporter shares his experience about the development, installation, testing and operation of the AlphaHeatDetectionCam. "Weather decks on RoRo and Ropax have no fire detectors. Fires onboard ships can be handled by ship crews only on early detection and prompt action" explains Peter van de Wardt. For Stena Line, this was a challenge to solve. They contacted Alphatron Marine for a solution. At the time there was no product on the shelf but Alphatron Marine was willing to think with us for a solution. From this point, we started a 1,5-year cooperation project and came with a unique innovative product, the AlphaHeatDetectionSystem.

Peter continues: "During these 1,5 years many challenges were met. Cable runs (cameras, supplies and internet connections) were done by the crew. For many months we did collect data and met our first big challenge: reflection from the sun. It took a long time of engineering writing new software and collecting data again. In the meantime, we did startup another project: heat cameras on enclosed decks. Here reflection will be your friend. Also, a live trial was held onboard Stena Scandinavica witnessed by the authorities which was very successful".

Sister ship Stena Transit is now also equipped with the AlphaHeatDetectionSystem on the weather deck.

"It is an innovative project which needed a lot of time and investment of both parties. The result is very good with high potential. It did meet our expectations", concludes Peter van de Wardt.

ANNEX H

Annexes related to Action 8-B, Guideline and solutions for safe electrical connections.

Annex H1 - Reefer connection box installation examples

Figure 1. Stena Flavia – connection box (1)

Figure 2. Stena Flavia – connection box (2)

Figure 3. Stena Flavia– connection box (3)

Fuses per phase inside connection box.

Reel system or manual cable coiling put on hooks.

Figure 4. Stena Hollandica-– connection box

Figure 5. Stena Hollandica - pilot test connection of charging station (not in use)

Figure 6. Napoles-– connection box

Figure 7. Stena Jutlandica– connection box (1)

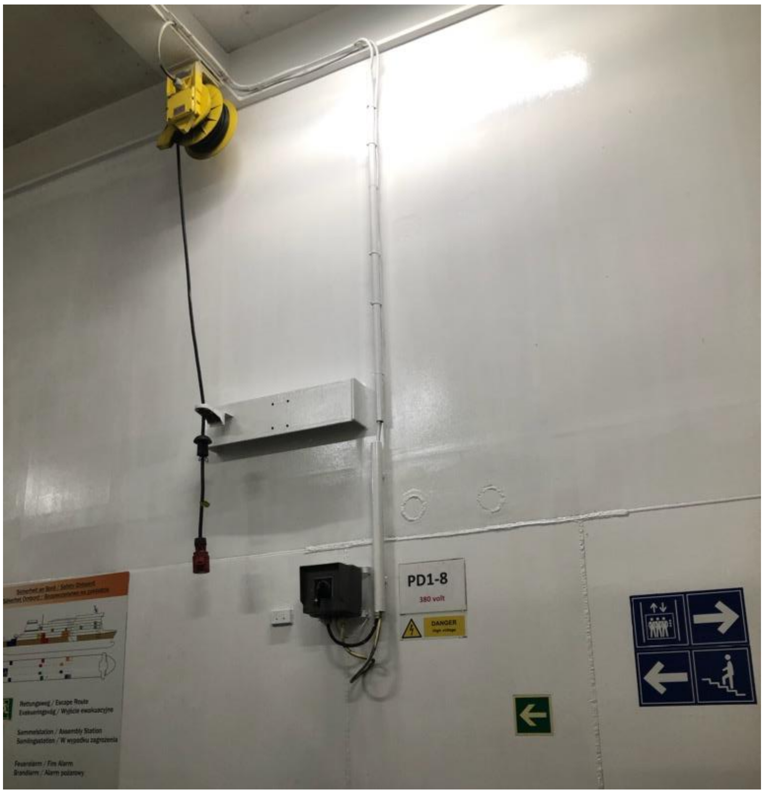


Figure 8. Stena Jutlandica– connection box (2)

Figure 9. Stena Jutlandica– connection box (3)

Annex H2 - Electric system examples

Figure 1. Stena Flavia, Circuit breaker in Engine Control Room, 2 groups (181-182 and 183-183)

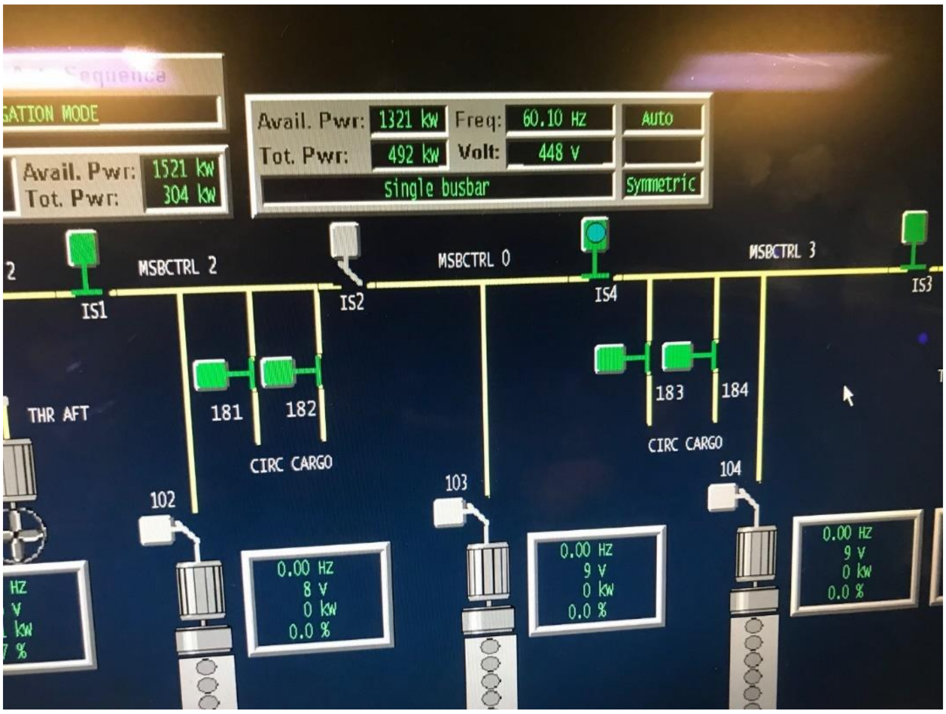


Figure 2. Stena Flavia, Connection of reefer connection groups to mainboard in 4 groups.

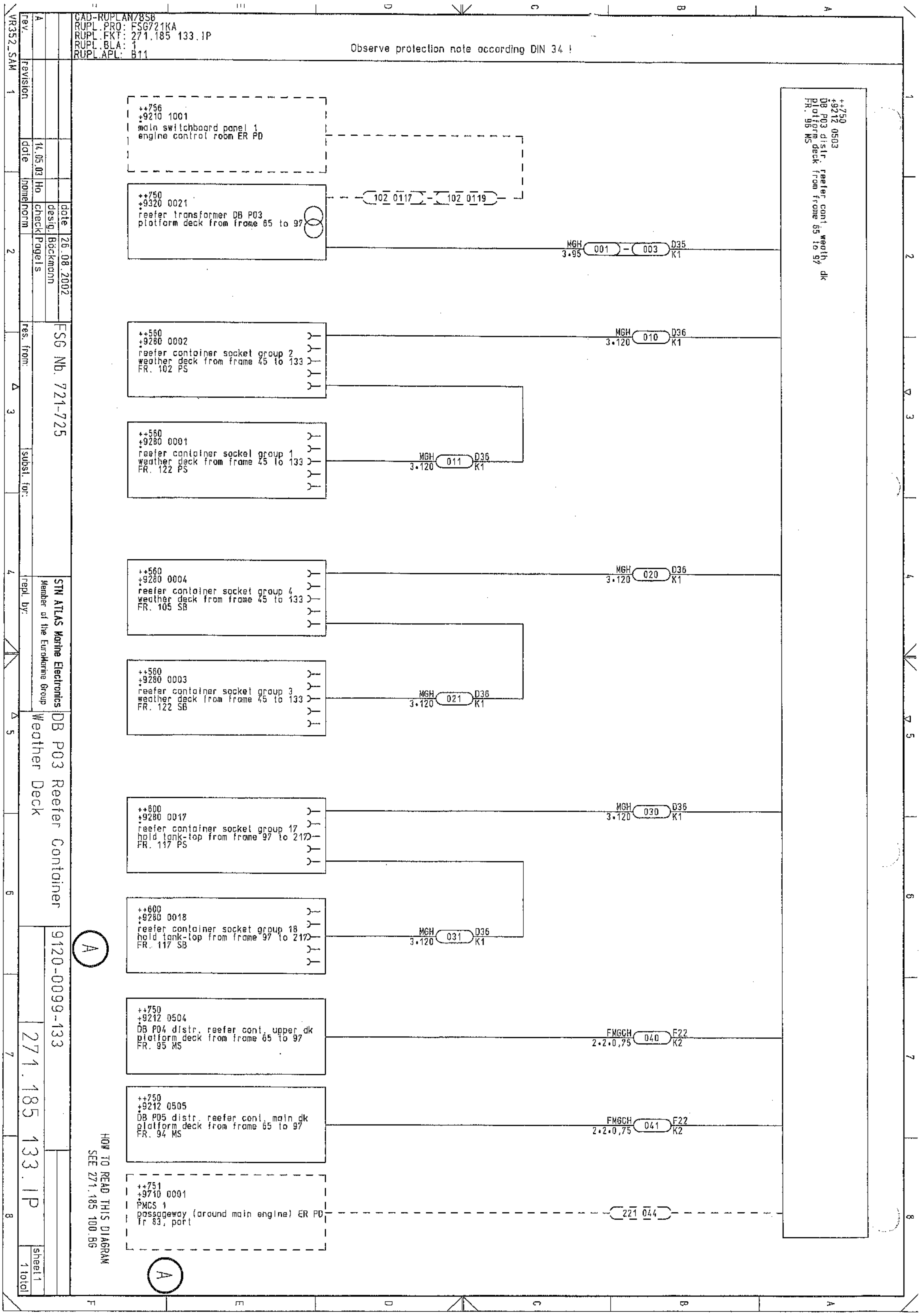


Figure 3. Magnolia Seaways electric diagram for reefer connection.s

Annex H3- Port operations procedure for a Reefer trailer (Stena)

	Port Operation Procedure Type 3 Fridged Trailer	Issue: 2	Page 1 (2)
Stena Line	Karlskrona- Gdynia	Date: 2017-05-12 Replaced: N/A	Sign: Operation Manager

4.1.3.1 ROUTINE TYPE 3 FRIDGED TRAILER

Routine for Type 1 or 3 to be followed and extra for fridged trailer

Check-in

- Bookings are made in Freightlink including the required goods temperature is noted in documents The booking also state of unit is to be runned on diesel or plugged in with electricity in port

Parked Export Area

- The unit will be put on line up area by the driver
- Driver is responsible to set unit running on the own cooler engine or plugged in with electricity according to booking. Plug in electrical cable must be done by assistance of stevedores
- When unit is dropped in port driver make sure aggregate is fully functional and unit in correct temperature

Temperature Check

- To be carried out and logged according to booking in Freight Link

Loaded by tugmaster

- When loaded on vessel ships crew responsible for **electricity plug in** and set unit in "cabels mode" and temperature check

Temperature check on vessel

- During the crossing several safety inspection rounds, including aggregate and temperature control are being made by ships crew

Unlashing Electricity Plug Out

- Just before arrival ships crew disconnect cables and switch to "diesel aggregate mode" and make sure running

Parked Import Area

- Stevedore check unit is in "diesel aggregate mode" or connect cables according to booking in Freightlink and temperature check.

	Port Operation Procedure Type 3 Fridged Trailer	Issue: 2	Page 2 (2)
Stena Line	Karlskrona- Gdynia	Date: 2017-05-12 Replaced: N/A	Sign: Operation Manager

RISKASSESMENT

Fault	Location	Action
Unit not run on "cabels mode" on vessel	Vessel	Unit to be unplugged and set in "diesel aggregate mode". To avoid exhausts on cargodeck unit to be runned by diesel intermittent to keep temperature Extra safety round to be done by crew Driver or customer to be contacted
Unit not run on "cabels mode" or "diesel mode"	Vessel	Driver or customer to be contacted
If temperature drop	Vessel	Driver or customer to be contacted
Unit not run on "diesel aggregate mode" in port	Port	Driver or customer to be contacted
Unit not run on "diesel aggregate mode" or "cabels mode"	Port	Driver or customer to be contacted
If temperature drop	Vessel	Driver or customer to be contacted
Temperature is unknown at booking time	Terminal	Company must tell when they book. It should be forced when they book to tell the temperature in the system, or we ask them during check-in

Annex H4 - Vessel operation manuals for reefer connection (Stena)

Operation of Reefer Units				
Version No. 1	Revision Date. 2014-01-30	Document ID. SOM-0067	Page. 1	

SOM chapter: 7 **SMM reference:** SMM-0187

Validity: Mecklenburg-Vorpommern

Operation of the refrigerated container connections

The following refrigerated container sockets for 400 V supply voltage are available:

- Deck 3: 18 pcs. (8 pcs. port / 8 pcs. starboard / 2 pcs. fore side)
- Deck 4: 22 pcs. (5 pcs. port / 6 pcs. starboard / 11 pcs. midship)
- Deck 5: 11 pcs. (5 pcs. port / 6 pcs. midship)

Connecting the refrigerated containers:

- Determine whether the connection to the cooling container must be 4 or 5-pin.
- Determine the position of the earthing. At 3, 6 or 9 o'clock (label on refrigerated container connection 3, 6 or 9 o'clock). The earthing made in cross-section is greater than the other poles.
- Lay appropriate extension cable and connect to the refrigerated container and the on-board socket.
- Switch to the on-board refrigerated container socket switch.
- Lorry driver starts the refrigeration of the container and checks the direction of rotation of the fan.

Disconnecting the refrigerated containers:

- Switch off the on-board refrigerated container switch.
- Remove extension cable from the refrigerated container and from the on-board refrigerated container socket.

Refrigerated Units (Area North Sea)				Stena Line
Version No. 5.2	Revision Date. 2019-02-27	Document ID. SOM-0062	Page. 1	

SOM chapter: 7 **SMM reference:** SMM-0187

Validity: All ships in area North Sea

General:
Running of diesel driven refrigeration plants is only permitted on open cargo decks. In enclosed vehicle decks it is prohibited to use diesel driven plants because of the fire/health hazard. In the enclosed vehicle decks refrigerated units which requiring refrigeration during sea passage must be plugged into the ship's electrical system.

Trailing cables to/from vehicles are to be protected at all times from possible physical damage by other vehicles. Care must be taken in determining the cable run to ensure there is no hazard to passengers/crew whilst entering/leaving the vehicle deck. The ETO should be informed regarding damage to cables, sockets and breakers. Unused cables are stored appropriately to avoid any damage or hazardous situations.

Procedure accompanied RoRo/Self drives:

- The truck driver will plug/unplug cables from refrigerated unit into the ship's electrical system, the loading officer or his deputy will assist when required.
    - If there is a problem with the power supply or the refrigerated unit will not run on the ships power the Engine Control Room or ETO will be contacted.

- Medicine/Mushroom procedure, for accompanied units (Self drives) only:
    - At (freight) check-in the drivers indicate their cargo is a 'Mushroom' or 'Medicine' cargo. The cargo should be booked as such too, so at (freight) check-in they will verify this.
    - The truck drivers will receive a yellow A4 paper, stating 'MUSHROOMS' or 'MEDICINES' which they need to put behind their windscreen.
    - Additionally they receive a white sticker stating either 'MUSHROOMS' or 'MEDICINES' which needs to be put around the plug that is inserted in the trailer.
    - This sticker indicates that the plug should remain plugged in until the driver himself takes it out or someone from the ship with the driver present, so the driver himself can change the reefer unit over to diesel.

Procedure un-accompanied RoRo/trailers:

- <u>Tug driver, loading port, shore side operation:</u>
    - Before connecting the trailer to bring the trailer on board the tug driver will check the temperature of the unit with the booked temperature in the port system (only in HVH and R'dam).
    - If there is a difference in set temperature and booked temperature it will be reported in the port system, freight operations will act on the difference in temperature and contact the customer.

Refrigerated Units (Area North Sea)				Stena Line
Version No. 5.2	Revision Date. 2019-02-27	Document ID. SOM-0062	Page. 2	

The tug driver or foreman may contact freight operations directly advising them about the temperature.

- Ships operation:

  Arrival of unit on board:
  - The reefer units should be checked by the loading officer or his deputy (AB/ETO). And as soon as possible after the arrival of the reefer on board, check the unit and plugged it in, following the steps on the 'CL-0161 - Plug-in Guide' and filling in the 'CL-0158 - Reefer list'.
  - The ships staff has no knowledge of the manifest temperature and will only check the actual temperature against the set temperature.
  - When there is a malfunction on the reefer unit or difference in real temperature and set temperature, the loading officer needs to be informed. He will contact the Stevedoring foreman and inform him about the situation. The foreman will contact freight operations and they will contact the customer and verify what should be done according to the customer.

  In port of discharge:
  - The loading officer takes care that prior to discharge all refrigerated trailers have been disconnected and are running on the diesel engine. While preparing the reefer unit for discharge from the ship (check temperature, plug out, switch to diesel), following the steps on the 'CL-0161 - Plug-in Guide' and filling in the 'CL-0158 - Reefer list'. When a malfunction is noticed at discharging the trailer, the loading officer needs to be informed who will contact the Stevedoring foreman. Stevedoring will take it off the ship and they will inform freight operations who will inform the customer, who will act upon that.
  - Keep 'CL-0158 - Reefer list' forms at least 12 months after the transit of the reefer unit.

- Discharge port, shore side operation:
  - When discharging the reefer the tally (checker) or tug driver from the receiving port will check the set temperature with the manifested temperature (only in HVH and R'dam).
  - In case there is a difference in set temperature and the manifested temperature of 5 degrees or more, the freight operations staff has to be informed with a copy to the claims department Stena Line, the freight operations staff will inform the customer accordingly.

Procedure for isolating:

When the vehicle deck electrical socket system is not in use (e.g. dry-dock), it is to be isolated as follows:-

a. Individual Sockets - switched off.

b. Distribution Board Switches - positioned off.

c. Main Switchboard - distribution board supply breaker switched off.

Plug-In Guide			
Version No. 1.1	Revision Date. 2019-02-27	Document ID. CL-0161	Page. 1

PLUG-IN GUIDE

CHECKS BEFORE CONNECTING

- RUNNING ON DIESEL
- ABNORMAL NOISES
- VISIBLE DAMAGES
- ENGLISH LANGUAGE ON DISPLAY
- ACTIVE ALARMS ON DISPLAY
- ACTUAL TEMPERATURE SAME AS SET TEMPERATURE

CONTACT LOADING OFFICER IF ANY OF THE ABOVE IS NOT CORRECT OR IN CASE OF DOUBT

IF ALL IN GOOD ORDER THEN **TURN OFF REEFER UNIT**, CONNECT CABLE **TURN ON AGAIN** AND CHANGE FROM DIESEL TO ELECTRIC

CHECKS AFTER CONNECTING

- RUNNING ON ELECTRIC
- ABNORMAL NOISES
- ACTIVE ALARMS ON DISPLAY

CONTACT LOADING OFFICER IF ANY OF THE ABOVE IS NOT CORRECT OR IN CASE OF DOUBT

CHECKS BEFORE DISCONNECTING

- RUNNING ON ELECTRIC
- ABNORMAL NOISES
- ACTIVE ALARMS ON DISPLAY
- ACTUAL TEMPERATURE SAME AS SET TEMPERATURE

CONTACT LOADING OFFICER IF ANY OF THE ABOVE IS NOT CORRECT OR IN CASE OF DOUBT

IF ALL IN GOOD ORDER THEN **TURN OFF REEFER UNIT**, DISCONNECT CABLE **TURN ON AGAIN** AND CHANGE FROM ELECTRIC TO DIESEL

CHECKS AFTER DISCONNECTING

- RUNNING ON DIESEL
- ABNORMAL NOISES
- ACTIVE ALARMS ON DISPLAY

CONTACT LOADING OFFICER IF ANY OF THE ABOVE IS NOT CORRECT OR IN CASE OF DOUBT

UNCONTROLLED WHEN PRINTED

Electrical Supply to Refrigerated Vehicles (Stena Superfast VII,VIII,X)				Stena Line
Version No. 1	Revision Date. 2019-02-09	Document ID. SOM-1726	Page. 1	

SOM chapter: 7.3 **SMM reference:**

Validity: Stena Superfast VII/VIII/X

The connection/disconnection of refrigerated vehicles to/from the vessel's electrical supply is the responsibility of the Electrical Officer but a suitably trained member of staff (normally deck crew) may connect/disconnect after suitable training.

The driver of the refrigerated vehicle should be present unless the refrigerated unit is an unaccompanied trailer.

Before the vessel arrives in port those Plug-ins in use are to be disconnected by a designated crew member.

When not in use all refrigeration sockets are to be switched off locally.

All connections/disconnections should follow the procedures outlined below.

CONNECTION/DISCONNECTION PROCEDURES

CONNECTING	***DISCONNECTING***
Switch off units own power supply	Switch unit off ship's supply
Socket switch OFF	Socket switch OFF
Plug inserted	Plug removed
Socket switch ON.	Start unit on its own power
Start unit on ship's supply	Record final temperature
Record unit's Reg No. & start temp.	

Electrical Officer or designated deputy must not connect the refrigerated vehicle if he is in any doubt as to the vehicles suitability as to electrical integrity or compatibility.

In such a case the matter must be reported to the Duty Chief Engineer and the Deck Officer advised.

After connection the vehicles driver is to report if the machinery is rotating in the correct direction, if not the designated crew member is to take corrective action using the phase reversal switches.

During connection of reefer switches it is essential that the earth indication lamps on the 440 volt system are closely and continuously monitored through the period of connection.

In the event of a failure of the electrical equipment of a reefer wagon during a voyage the ships supply must be disconnected as above. The date and time of any such incident is to be recorded in the deck log book.

TRAILING LEADS, CABLES ETC.

Trailing cable to/from vehicles are to be protected at all times against damage by other vehicles etc.

Cable runs should be such that there is no danger to passenger's etc.

Electrical Supply to Refrigerated Vehicles (Stena Superfast VII,VIII,X)				Stena Line
Version No. 1	Revision Date. 2019-02-09	Document ID. SOM-1726	Page. 2	

After disconnection from vehicles all cables are to be correctly stowed back in their cable reel.

If the self-stowing system fails, the cable should be tied up to make it safe and reported to the Engine Control Room for remedial action to be taken.

DAMAGE TO SHIPS EQUIPMENT

The designated crew member is to undertake a physical examination of plugs/socket and trailing leads before and after usage of the reefer system.

Any defect so noted should be reported to the Chief Engineer and dealt with as required. All defects to be noted in the Planned maintenance system.

CHECK OF SYSTEM

The reefer socket system (plugs, cables, cable reels, switches, breakers, alarm functions, insulation and continuity) is to be checked by the Electrical Officer at intervals laid down in the planned maintenance system.

Procedure for handling refrigerated units (Stena Baltica)			
Version No. 1	Revision Date. 2018-09-21	Document ID. SOM-1099	Page. 1

SOM chapter: 7 **SMM reference:** SMM-0187

Validity: Stena Baltica

1. PRELIMINARY

- Only those persons designated by the Chief Engineer are permitted to connect/disconnect cables from refrigerated vehicles to the ship's electrical system.
- All those tasked with connecting refrigerated units must receive appropriate training and be issued with a certificate as a record of the training

2. UNIT LOADING

- The Cargo Officer will advise the designated person of all vehicles that require to be connected to the ship's electrical supply.
- When a refrigerated vehicle arrives on board it will be directed to the designated stowage position.
- For accompanied units designated crew will connect the cable to ship's electrical supply and then give it to the accompanied lorry driver who will connect the cable to his unit. After confirmation from the driver that everything is set properly, the crewmember will switch on the ship's supply. Driver is to confirm that electrical engine is running properly.
- For unaccompanied units, after loaded by the stevedores, designated crew will connect the cable to ship's electrical supply and then connect it to the unit.
  a) For automatic plug in units (smart reefers) crewmember shall switch on the ship's supply
  b) For manual operated plug in units crew member shall switch off the unit power supply on the fridge panel, change from diesel mode to electric, switch on the ship's supply and then switch on the unit on the fridge panel.

After that the crewmember will check if electrical motor starts and runs properly.

- Diesel driven units can be only stowed on open deck 5.

3. UNIT DURING SEAPASSAGE

- Unit shall be inspected (temperature control) every two hours during crossing by the Watchman on duty.
- Any problems with the unit must be reported to Officer on duty immediately.

Procedure for handling refrigerated units (Stena Baltica)				Stena Line
Version No. 1	Revision Date. 2018-09-21	Document ID. SOM-1099	Page. 2	

4. UNIT DISCHARGING

- After arrival designated crewmember will switch off the power supply to the unit and unplug the cable.
- Accompanied unit should be then operated by the driver.
- Manual operated unaccompanied trailer should be switched off, set to diesel mode and then switched back on. Crew member is to ensure that trailer is running on diesel properly.

5. TRUBLESHOOTING

- Any defective units are to be refused and/or brought to the attention of the stevedores for repair prior to being accepted for loading.
- If standard five pin cable does not suit the unit then the four pin adaptor shall be used.
- If unit is powered by 230V then special adaptor and designated socket shall be used.
- If electric motor does not start when unit is plugged in then try to make following steps:
  a) Reset the unit on the panel
  b) Change the phase switch
  c) Change the socket
  d) Change the cable

If all above does not solve the problem then the ECR or ETO is to be contacted. The problem will then be investigated further. If there is still a problem the Cargo Officer is to be informed. A decision can be then made in good time to accept the vehicle or have it returned ashore.
If unit is accepted for shipment it should be unplugged and sent to open deck 5 to run on diesel mode. Driver or charterer is to be contacted.

6. MAINTENANCE AND HANDLING OF SHIP'S POWER SUPPLY EQUIPMENT

- All defects on sockets, breakers and cables are to be noted and reported to the Cargo Officer. Damaged cables are then to be taken to ETO's workshop for repair.
- Unused cables are to be disconnected from ship's power supply and stored appropriately to avoid damage from passing vehicles.
- The trailing cables which connect the cargo unit to the vessels system are to be protected at all times from physical damage which could be caused during cargo operations. Particular care should be also taken in determining the path of the cable to minimize the potential for damage and the potential to create a trip hazard for passengers, drivers and crew members when transiting the cargo deck areas.
- Unused sockets to be switched off and secured with cap.

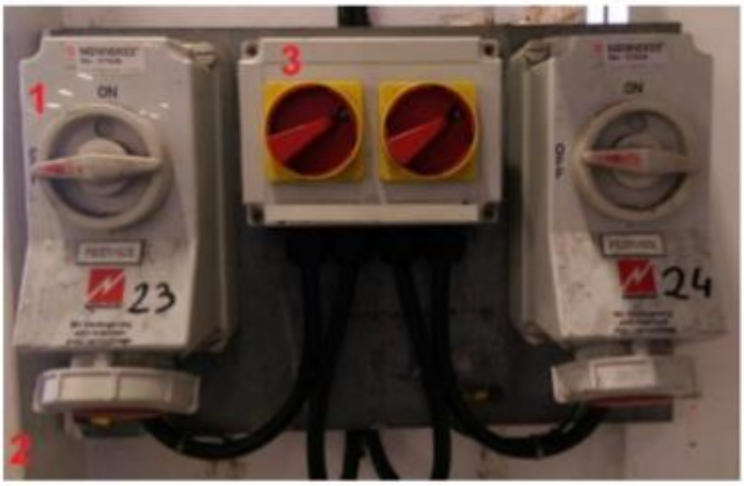
Procedure for handling refrigerated units (Stena Baltica)				Stena Line
Version No. 1	Revision Date. 2018-09-21	Document ID. SOM-1099	Page. 3	

- All reefer power sockets and cables should be inspected, tested and maintained as per the vessels planned maintenance system. At least once per month they should be switched on and off to ensure correct operation. If there are prolonged periods where they are not used, consideration should be given to more frequent checks to ensure when required they can be utilized without any delay to cargo operations.

7. SHIP'S POWER SUPPLY DESCRIPTION

- The vessel is equipped with 56, 3-phase 400V 32A reefer sockets and 20, single phase 230V 16A electric sockets located on the car decks.

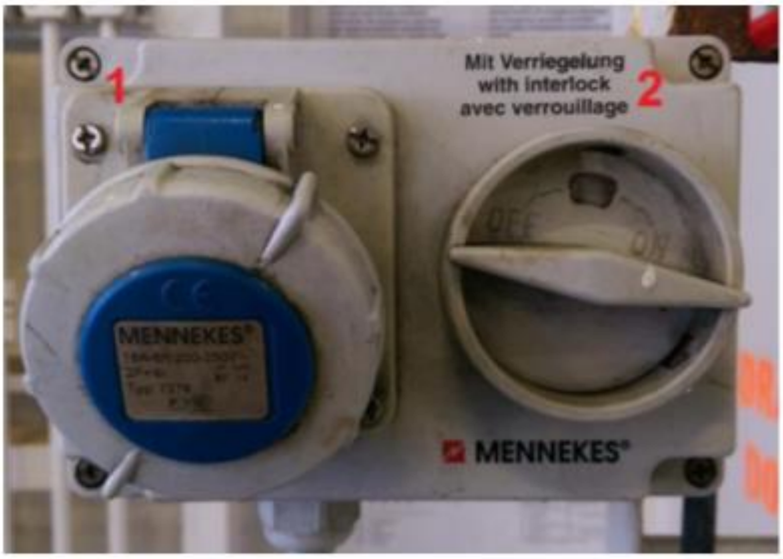
3-phase 400V 32A reefer socket



1. Power On/Off Switch
2. Cable socket with interlock and securing cap
3. Phase switch
   a) ↖ switch position: left channel in phase marked "I"
   b) ↑ switch position: no voltage marked "0"
   c) ↗ switch position: right channel in phase marked "II"

Procedure for handling refrigerated units (Stena Baltica)			
Version No. 1	Revision Date. 2018-09-21	Document ID. SOM-1099	Page. 4

Single phase 230V 16A electric sockets



1. Cable socket with interlock and securing cap
2. Power On/Off Switch

Note: Special adaptor may be necessary to connect the unit.

8. EXAMPLES OF REFRIGERATED UNITS OPERATION

Smart Reefer (Automatic Operation)

Switching from Diesel to Electric

Units equipped with the SmartPower option only.

If the Electric to Diesel Autoswitch Enabled feature in Guarded Access is set YES then the unit will automatically switch to Electric Mode operation when standby power is connected and available.

If the Electric to Diesel Autoswitch Enabled feature in Guarded Access is set NO then the prompt screen shown in Figure 35 will appear when standby power is connected and available.

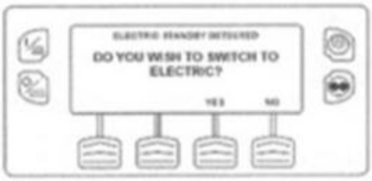


Figure 35: Electric to Diesel Autoswitch Enabled feature in Guarded Access Set to NO

Electric Mode operation will briefly be confirmed. If unit operation is required the electric motor will start as shown in Figure 36 STARTING THE ELECTRIC MOTOR.

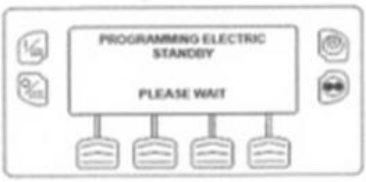


Figure 36: Electric Motor Start

Switching from Electric to Diesel

Units equipped with the SmartPower option only.

If the Diesel to Electric Autoswitch Enabled feature in Guarded Access is set YES then the unit will automatically switch to Diesel Mode operation when standby power is turned off or is no longer available.

If the Electric to Diesel Autoswitch Enabled feature in Guarded Access is set NO then the prompt screen shown in Figure 38 will appear when standby power is turned off or is no longer available.

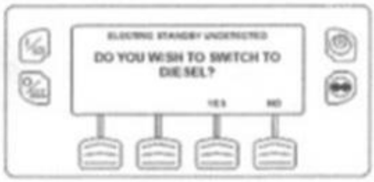


Figure 38: Prompt Screen

If YES is selected then the display will briefly show the screen in Figure 39. Then Diesel Mode will briefly be confirmed. If unit operation is required the diesel engine will start as shown previously in STARTING THE DIESEL ENGINE.

Figure 39: YES Selected

Procedure for handling refrigerated units (Stena Baltica)			
Version No. 1	Revision Date. 2018-09-21	Document ID. SOM-1099	Page. 6

Logicold Vector 1800 (Manual Operation)

Unit loading:

1. Place "START RUN/OFF" switch to "OFF" position.
2. Place "STANDBY/ENGINE" switch to "STANDBY" position.
3. Plug in the cable and turn on the ship's supply.
4. Place "START RUN/OFF" switch to "START RUN" position.

Unit discharging:

1. Place "START RUN/OFF" switch to "OFF" position.
2. Turn off the ship's supply and unplug the cable.
3. Place "STANDBY/ENGINE" switch to "ENGINE" position.
4. Place "START RUN/OFF" switch to "START RUN" position.

Annex H5- Reefer connection and monitoring on Suecia Seaways

Figure 1. Reefer connection on upper deck of Suecia Seaways

Figure 2. Socket on reefer unit

Figure 3. Control panel on reefer unit

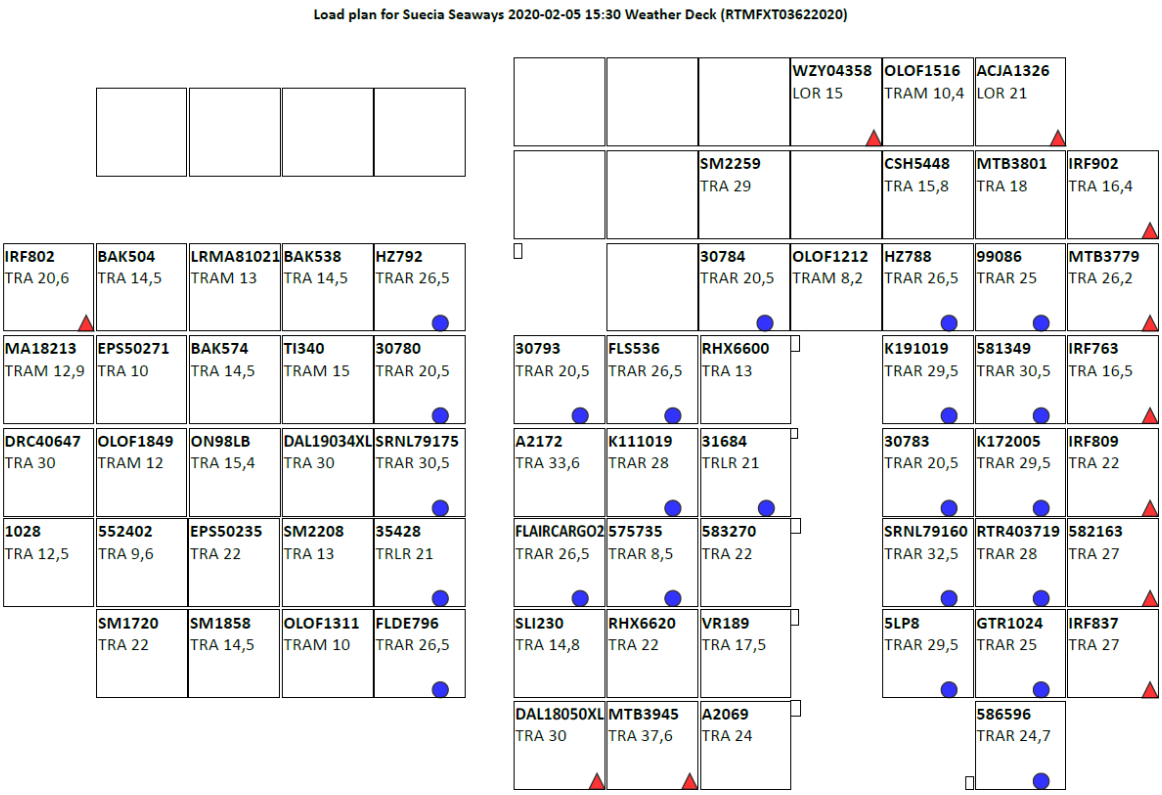


Figure 4. Stowage plan at Suecia Seaways, blue dots are reefers, red triangles are DG

Suecia Seaways **Temperature List for Plugin and Diesel units** TOR DFDS SEAWAYS

PrintDate: 2020-02-05

Voyno: RTMFXT03622020 Saildate: 2020-02-05 Arr. date: 2020-02-05 RTM - FXT IG no.: NLRTM20526079

ReleaseNo/Unitno	Contents	Set. Temp	MaxTemp	MinTemp	IMO	UN	Nominee	Customer	PlugInstruction	Diesel	Plugin
48560173/K191023	Foodstuffs	8	8	8			7175	A. Visbeen & Zonen BV	Pol: Yes Vessel: Yes Pod: Yes	YES	NO
48560175/K111019	Frozen Foods	-21	-21	-21			7175	A. Visbeen & Zonen BV	Pol: Yes Vessel: Yes Pod: Yes	YES	NO
48560382/5LP8	Frozen Foods	-21	-21	-21			7175	A. Visbeen & Zonen BV	Pol: Yes Vessel: Yes Pod: Yes	YES	NO
48560383/K172005	Frozen Foods	-21	-21	-21			7175	A. Visbeen & Zonen BV	Pol: Yes Vessel: Yes Pod: Yes	YES	NO
48560384/K191019	Fruit and Veg	8	8	8			7175	A. Visbeen & Zonen BV	Pol: Yes Vessel: Yes Pod: Yes	YES	NO
48560410/99086	Foodstuff	2					12049	HSF Logistics Nijmegen BV	Pol: Yes Vessel: Yes Pod: Yes	YES	NO
48560444/SPOT002	flowers	4	4	4			52146	Freshlinc Ltd	Pol: Yes Vessel: Yes Pod: Yes	NO	YES
48560445/FLAIRCARGO 2	FLOWERS	4	4	4			52146	Freshlinc Ltd	Pol: Yes Vessel: Yes Pod: Yes	NO	YES
48560446/FLDE796	FLOWERS	7	7	7			52146		Pol: Yes Vessel: Yes Pod: Yes	NO	YES
48560447/FLS536	FLOWERS	4	4	4			52146		Pol: Yes Vessel: Yes Pod: Yes	NO	YES
48560448/STK13	FLOWERBULBS	5	5	5			52444	Steenhoven Transport B.V.	Pol: Yes Vessel: Yes Pod: Yes	NO	YES
48560451/GTR1024	FLOWERS	5	5	5			59032	H.Z. Logistics B.V.	Pol: Yes Vessel: Yes Pod: Yes	NO	YES
48560455/HZ851	LEVENSMIDDELEN	2	2	2			59032	H.Z. Logistics B.V.	Pol: Yes Vessel: Yes Pod: Yes	NO	YES
48560456/HZ792	FLOWERS	5	5	5			59032	H.Z. Logistics B.V.	Pol: Yes Vessel: Yes Pod: Yes	NO	YES
48560458/HZ862	FLOWERS	5	5	5			59032	H.Z. Logistics B.V.	Pol: Yes Vessel: Yes Pod: Yes	NO	YES

Figure 5. Sample reefer temperature list Suecia Seaways

DFDS WD **Reeferlist** ***Vessel Suecia Seaways***

Voy. Nr. RTM => FXT

Date 05/02/2020

No.	Reefer no. / POSITION on deck	Switched Off	Plugged	Diesel driven	Setpoint on arrival	Temp. on arrival	New setpoint	1st time	2nd time
	GTR 1024 F2	Y / N	Y / N	Y / N	5	5		4,9	
	586596 F2	Y / N	Y / N	Y / N	-20	-18		-17,3	
	30 783 F2	Y / N	Y / N	Y / N	7	7		7,3	
	K111019 F2	Y / N	Y / N	Y / N	10	10		9,9	
	K172005 F2	Y / N	Y / N	Y / N	-21	-22		-21,9	
	SRNL 79 160 F2	Y / N	Y / N	Y / N	-25	-25		-24,2	
	RTR 4 03 719 F3	Y / N	Y / N	Y / N	-3	-2		-2,8	
	FLDE 796 F3	Y / N	Y / N	Y / N	7	7		7	
	581349 F3	Y / N	Y / N	Y / N	-25	-25		-22,6	
	35428 F3	Y / N	Y / N	Y / N	15/6	15/		14/6	
	5LP8 F3	Y / N	Y / N	Y / N	-25	-27		-24,1	
	SRNL 79175 A4	Y / N	Y / N	Y / N	-25	-24		-24,7	
	99086 A4	Y / N	Y / N	Y / N	1	1		1,4	
	HZ792 A6	Y / N	Y / N	Y / N	5	6		8,4	
	30 780 A5	Y / N	Y / N	Y / N	7	8		7,3	
	HZ766 A6	Y / N	Y / N	Y / N	5	4		4	
	575735 A6	Y / N	Y / N	Y / N	6	5		8,6	
	HZ792 A6	Y / N	Y / N	Y / N	5	9		7,9	
	30 793 A7	Y / N	Y / N	Y / N	7	8		7,3	
*	FL AIR CARGO 2 A8	Y / N	Y / N	Y / N	4	-5		9,2	
	FLS 536 A8	Y / N	Y / N	Y / N	4	-5		3,2	
	31684 A7	Y / N	Y / N	Y / N	5	5		4,8	
	K111019 A8	Y / N	Y / N	Y / N	-21	-21		-23	
	30 784 A8	Y / N	Y / N	Y / N	6	6		9,8	

Remarks

Signature

Function

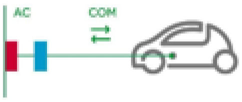
Figure 6. Sample temperature check list

Annex H6 - Charging of electric battery cars

Laddstandards

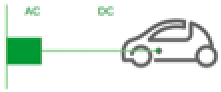
IEC (International Electrotechnical Commission) har definierat fyra olika moder, för laddning av elfordon:

Mode 1
Långsam laddning från ett vanligt eluttag (Schuko) 1 eller 3-fas, max 16A



Mode 2
Långsam laddning från ett vanlig eluttag 1 eller 3-fas, men med någon form av skydd och styrning av laddströmmen. Max 32A.

Mode 3
Långsam eller snabb laddning med speciell kontakt med tillhörande skydd och styrning av laddfunktionen.



Mode 4
Snabbladdning DC (likström). Exempel på laddare är det Japanska systemet CHAdeMO och det Europiska CCS (Combined Charging System).

Cable integrity is checked before charging starts, charging station is continuously self-checked to secure internal safety functions in order. (Source ChargePoint)

<u>Charging times</u>

Type	Example	Battery size	Charging current	Car max received charging power	Charging station power	Charging time "0->100%" [h]
Hydrid 1-phase	Mitsubishi Outlander	12 kWh	AC 16 A	3,7 kW	11kW/3-phase (3,7 kW)	4 h
Electric 1-phase	Nissan Leaf E+	62 kWh	AC 32 A	7,4 kW	11kW/3-phase (3,7 kW)	23 h
Electric 3-phase	Renault Zoe ZE50	52 kWh	AC 63 A	43 kW	11kW/3-phase	6 h

(Source ACS)

<u>BMS function vs charging station function, communication</u>

Relay controlled, if cable in place and intact and BMS system reports that car ok, then charging will start, Mode 3

Next level is to transfer more sophisticated information from BMS to Charger Station, such as temperatures, Mode 4. Only for DC charging.

BMS information may be transferred into ship safety system, by means of OCPP communication protocol.

Annex H7 - Firesafe I report extracts

3.2.1. Connection boxes RCO El 1

With regards to socket outlets (connection boxes) on ro-ro-spaces there are some requirements in different classification societies rules that could be applicable. The requirements are furthermore not exactly the same for different societies, which means that the protection on different ships will vary. During the identification of RCMs, a large number of proposals where put forward with regard to protection of the connection boxes. During the workshop the project summarized the most important of these into one RCO. This RCO is called Robust Connection Boxes. Some or all of the proposals in this RCO may already be in place on a specific ship depending on flag, class and age. The impact of upgrading, installing and maintaining the connection boxes in line with the requirements below could become a uniform IMO standard. The features for the robust connection boxes are:

- Earth fault breakers to be installed (see separate discussion below)
- Increased maintenance of the connection boxes
- IP-class (e.g. IP56)
- Individual circuit breakers
- Individual and interlocked switches
- Secured cables

Examples of requirements in the regulations and in the rules of some classification societies are given here.

Circuit breakers

In SOLAS chapter II-1/45.6.1 it is required that each separate circuit shall be protected against short circuit and overload. A separate circuit may consist of several sub-circuits and a definition of final sub-circuit can be found in LR and DNV GL rules.

> LR p6 ch2 sec1 1.6.8. A `final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.
>
> *LR p6 ch2 sec 13 13.6 Socket outlets and plugs*
> *13.6.1. The temperature rise on the live parts of socket outlet and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.*
>
> *13.6.2. All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the 'on' position.*
>
> *13.6.3. Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.*
>
> *DNVGL p4 ch8 s10 2.1.1 f) All equipment of smaller type (luminaires, socket outlets etc.) shall be protected against mechanical damage either by safe location or by additional protection, if not of a rugged metallic construction.*
> *2.2.1 Cargo holds IP55 + reg II-2/20.3.2*

90

P4 ch8 s8 1.1 Socket outlets and plugs
1.1.1 General
a) Socket outlets and plugs with a rated current not exceeding 63 A in AC installations and 16 A in DC installations, shall be constructed for making and breaking the rated current by insertion and withdrawal of the plug, unless they are provided with an interlock as described in b).
b) Socket outlets with a rated current above 63 A AC or 16 A DC shall be provided with interlocks so that the plug can only be inserted and withdrawn when the switch is in the "off" position.

Earth fault breakers (Residual current device)

When discussing safety of electrical systems one of the most important concerns is the protection from earth faults. An earth fault could be described as a fault where the current flows from the live part to earth instead of back through the neutral part in a one phase system. In a three-phase system, it is leakage from one of the phases to earth. A small leakage is not uncommon (especially for refrigerated units on trucks) and if it is small enough it could be harmless. When reaching to about 30 mA it will become hazardous to humans and could even cause a risk to life depending on the duration (IEC Report 479-1 'Effects of current passing through the human body'). This is of course an important concern that also needs to be addressed. Protection could be achieved with an earth fault breaker (also called Residual Current Device RCD).

With regards to fire safety the leakage needs to be larger in order to cause a fire. According to Kidd 1985 a RCD which cuts of at 100 mA and after 200 ms will give a good protection against start of a fire. The following example is also given: "If an overcurrent protective device rated at 5 A were the only means available to protect against such a situation well over 1 kW would need to be dissipated in the developing fault path before the condition could be detected". This could be compared to electrical barbeque igniters that uses 500-800 W.

In IACS rec. no 137 the problems with earth faults and road freight units are discussed. They recommend that RCD protection is installed for all outgoing distribution circuits to road freight units. The rec. does not give any advice on the sensitivity of the RCD.

It should be noted that the electrical system on ships could be of different types with regards to the neutral, earth and the phases. In some cases, the equipment is locally earthed. It is important that the technical details of the system are taken into account when installing RCDs. For supplying power to reefer, it would be preferable to use an insulation transformer, in order to isolate reefer circuits from ship's distribution. The connection of systems like reefers which are not always in good condition and not well maintained is a frequent source of insulation failures. This transformer is also a means to change the distribution system from IT to TN-S or TT, which could be easier to manage.

Here are some examples of SOLAS and class requirements for earth fault protection:

> *SOLAS II-1/45.4.2. When a distribution system, whether primary or secondary, for power, heating or lighting, with no connection to earth is*

used, a device capable of continuously monitoring the insulation level to earth and of giving an audible or visual indication of abnormally low insulation values shall be provided.

BV Pt C ch 2 sec 3:
3.11 Refrigerated containers.
3.11.1 Where the ship is intended to carry a large number of refrigerated containers, provision of suitable means for preventing earth faults on containers from affecting the main distribution system is to be made (galvanic isolation, tripping of the faulty circuit).

LR Part 6 ch 2 sec 6
6.4 Protection against earth faults
6.4.1. Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2. If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3. The rated short-circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4. Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in 6.4.2 because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

DNVGL part 4 ch 8 sec 2
7.1.2 Insulation fault
d) On systems with low-resistance earthed neutral automatic disconnection of circuits having insulation faults shall be arranged. This earth fault protection shall be selective against the feeding network. For low resistance earthed neutral systems the disconnection shall operate at less than 20% of minimum earth fault current.
f) For direct-earthed systems (i.e. TN-S, TN-C-S and TT) the single or three phase effective overcurrent and short circuit protection is acceptable as earth fault protection.

3.2.2. Only allow ship cables and ship adapters RCO El 2

The cargo on ro-ro-passenger ships mainly consists of trucks, buses and cars. Some of these will request the possibility to get connected to the ships electrical system. The purpose could be to run reefer units on trucks or charging of electrical vehicles. On some ships this connection is done with cables and adapters brought by the drivers. It could also be possible for drivers to connect without the knowledge of the crew, (e.g. if they use an extension cord with multiple outlets). This means that unknown cables could be connected to the ship with possible increased risk of short circuit in cables and adapters, higher risk of overheated cables due to wrong size and higher risk of sparks from possible damaged cables.

Routines for maintenance and exchange of cables shall be further developed (cables shall be treated as consumables).

Ships cables (and especially fixed installed cables) are subject to a large number of requirements in the classification rules.

> *BV pC ch2 s9 1.1.1 Cables and insulated wiring are generally to be constructed in accordance with IEC Publications of the series 60092-3.., as well with the provisions of this Chapter.*
>
> *DNVGL p4ch8s9 8.1.1 Flexible electrical cables shall be constructed and tested in accordance with the technical requirements given through DNVGL-CP-0417 Flexible electrical cables.*

3.2.5. Only crew connections RCO El 5

One of the identified risks is caused by electrically connected cargo such as reefers and charging of electric cars. The equipment used for the connection are frequently used and handled under time pressure or by the drivers. This results in wear and tear of connection boxes, cables, cable connections and adapters. One proposal that also has been put forward in other projects is to only allow trained crew to connect and disconnect cables. A training program should be developed which should include training and routines for control of, care for and maintenance of cables (as well included in this RCO).

The crew shall be trained to identify faulty and risky connections and how to managing connections. Issues that should be covered include avoiding long cables and cable routing. Electricians and dedicated crew to do maintenance and keep equipment ship shape.

SOLAS II-2/16 Operations, does contain the requirement that the crew shall be given necessary information and instructions for the safe operation of the ship and its cargo. However, in most cases these operation booklets do not contain information at the level of detail about fire risks caused by electrical connections of vehicles that is proposed in this RCO.

> *SOLAS II-2/16.2 Fire safety operation booklets*
> *2.1. The required fire safety operational booklet shall contain the necessary information and instructions for the safe operation of the ship and cargo handling operations in relation to fire safety. The booklet shall include information concerning the crew's responsibilities for the general fire safety of the ship while loading and discharging cargo and while underway.*

Necessary fire safety precautions for handling general cargoes shall be explained.

3.2.6. Use of cable reeling drums RCO El 6

One method for protecting cables and to facilitate the handling of cables that has been developed is to install cable reeling drums. These are placed in appropriate locations in the ceiling of the ro-ro-space. The cable is rolled out when needed and (automatically) rolled in when disconnected. The main advantages are that the cables are protected when not used and that handling becomes easier. Drawbacks are costs, the requirement to pull all the line, the required installation space and the connection inside the drums are more difficult to inspect.

3.2.7. Plan for reefers RCO El 7

One fire hazard that is identified in many investigations is trucks and trailers with refrigeration units (reefers). It would be beneficial if the crew is aware of the exact location of the reefers that are carried onboard. First it could be possible to increase the possibility to detect a fire before it starts by increasing the frequency of the fire patrol where reefers are located. In case of a fire alarm with large amount of smoke the knowledge where reefers are positioned may help locate the fire. Furthermore the electric supply may be cut off to reefers close to a fire alarm.

This RCO proposes that reefers should be included in the Dangerous Goods plan or in a similar plan for those ships without dangerous goods. It could also be possible to include other identified high fire risk vehicles in the same manner.

Electrical connections on Ro-ro spaces

The risk from explosive vapours on ro-ro-spaces has been considered by the SOLAS convention for many years. In the work with the comprehensive review of chapter II-2 that lead to SOLAS 2000 amendments the requirements on electrical equipment on ro-ro-spaces were increased. For ships built before 1 July 2002 the requirements on the electric equipment were only applicable if explosive vapours might be expected in a space. This was also in the proposed text of the 2000 amendments II-2/20.2.2 sent to FP44:

> *"2.2 Electrical equipment and wiring*
> *.1 On any deck or platform, if fitted, in vehicle spaces on which explosive vapours might be expected to accumulate, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, equipment and wiring, if fitted, shall be of a type suitable for use in explosive petrol and air mixtures. (Part of Reg.37.2.2.1, Part of Reg.37.3.2.1, Part of Reg.38.4.1, Reg.53.2.4.1 & Reg.53.3)*
> *.2 In case of other than special category spaces below the bulkhead deck, notwithstanding the provisions in paragraph 2.2.1, in the closed vehicle spaces a height of 450mm from the deck and from each platform, electrical equipment of a type so enclosed and protected as to prevent the escape of spark shall be permitted as an alternative on condition that the ventilation system is so designed and operated as to provide continuous ventilation of the cargo spaces at the rate of at least ten air changes per hour whenever vehicles are on board. (Part of Reg.37.2.2.1, 53.2.4.2 & Reg.53.3)"*

However, at FP44 the text of the new II-2/20.3.2 was changed to the following which is also the present text:

> *"3.2 Electrical equipment and wiring*
> *3.2.1 Except as provided in paragraph 3.2.2, electrical equipment and wiring shall be of a type suitable for use in an explosive petrol and air mixture*.*
> *3.2.2 In case of other than special category spaces below the bulkhead deck, notwithstanding the provisions in paragraph 3.2.1, above a height of 450 mm from the deck and from each platform for vehicles, if fitted, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, electrical equipment of a type so enclosed and protected as to prevent the escape of sparks shall be permitted as an alternative on condition that the ventilation system is so designed and operated as to provide continuous ventilation of the cargo spaces at the rate of at least ten air changes per hour whenever vehicles are on board."*

The requirements in regulation "37 special category spaces on passenger ships" in the version of SOLAS that is still applicable to ships built before 1 July 2002, and this together with the interpretation that diesel fuel will not produce explosive vapours allows for connecting any cargo to the ships electrical system in enclosed spaces if no petrol fuelled vehicles are carried in the same space.

Furthermore, if petrol vehicles or any other vehicle that may cause the accumulation of explosive vapours are carried, all electrical equipment (including cars, trucks or reefers) shall be of a suitable type. According to most class and flag interpretations suitable type are equipment certified for Zone 1 below 450mm and for Zone 2 above 450mm with >10 air changes/h (IP 55 could be accepted).

For ships built after 2002 the requirements in 20.3.2 is applicable to all ro-ro-spaces without considering if there is any risk of explosive vapours. This means that any electrical equipment on closed ro-ro spaces shall comply with zone 1 below 450mm and zone 2 above 450mm, i.e. all reefers (or electric cars charging) must be above 450 mm and be classified as IP55 unless approved for ex-class Zone 1.

Annex H8 - Reefer unit manufacturer statement

For the following statements it is important to keep in mind that they are solely for the Thermo King refrigeration unit(s), and not in any way valid for any other brands or additional options installed on the trailer.

Thermo King is always keeping focus on a high level of safety around the handling, operation and use of our units, and we have undertaken some significant measures to provide such level of safety. Obviously we can't control how the unit is handled in the end, but we can provide the means and training for the operators to be able to handle the units according to the health and safety requirements.

Thermo King Trailer units have a number of fail-safe features.

- The units are equipped with an alarm feature which will shut down the unit if the controller detects a difference in the ration between the engine/electric motor rpm, and the alternator frequency.
    - If such a difference should occur – which could be caused by a broken drive belt, or a stuck pulley on a tensioner, then the units will shut down and trigger an alarm code (Code 48)
- Electric overload relays which protects the high voltage circuits from overloads
- Auto Phase correction which ensure that the electric motor and thereby the fans are turning in the correct direction.
- The unit controller can also be programmed NOT to auto-switch between Electric and Diesel operation in case the electric power supply should drop out. This could either be by a loss of supply power from the ship, or if the electric plug is removed from the unit.
    - This feature is normally disabled from the factory, but it might have been activated upon customer request. Normally customers who are going by ferries will be aware of this and have the feature disabled, but it would be advisable to check with the various customers using Stena Line.

ANNEX I

Annexes related to Action 10-B Weather deck fire extinguishment

ANNEX I1 Fire monitor installations – M/V Urd

Arrangement of fire monitors on M/V Urd is illustrated on Figure 1, where fire monitors are marked with red spots. Fire monitors are arranged on Deck 5 aft casings and on Deck 6 forward, aft of the accommodation, to cover Deck 4. There are no blind spots. Monitor specification is shown on Figure . Fire monitors are illustrated on Figure - Figure .

Figure 1. M/V Urd weather deck 4 – fire monitor arrangement

Figure 2. M/V Urd -Details of monitors

Figure 3. M/V Urd -Fire monitor 1&2

Figure 4. M/V Urd -Fire monitor 3

Figure 5. M/V Urd -Fire monitor 4

Figure 6. M/V Urd -View from monitor 5

Figure 7. M/V Urd -Illustration of throw length of monitor 5 (by wet deck surface), during smooth sea/wind conditions

ANNEX I2 Fire monitor installations – M/V Stena Gothica

Fire monitors arrangement on M/V Stena Gothica is illustrated on Figure 1, where three fire monitors are installed. Fire monitors are illustrated on Figure – 4.
For movie of operation of fire monitors see WP 5 reference information area on Teams.

Figure 1. M/V Stena Gothica - fire monitor configuration with coverage areas.

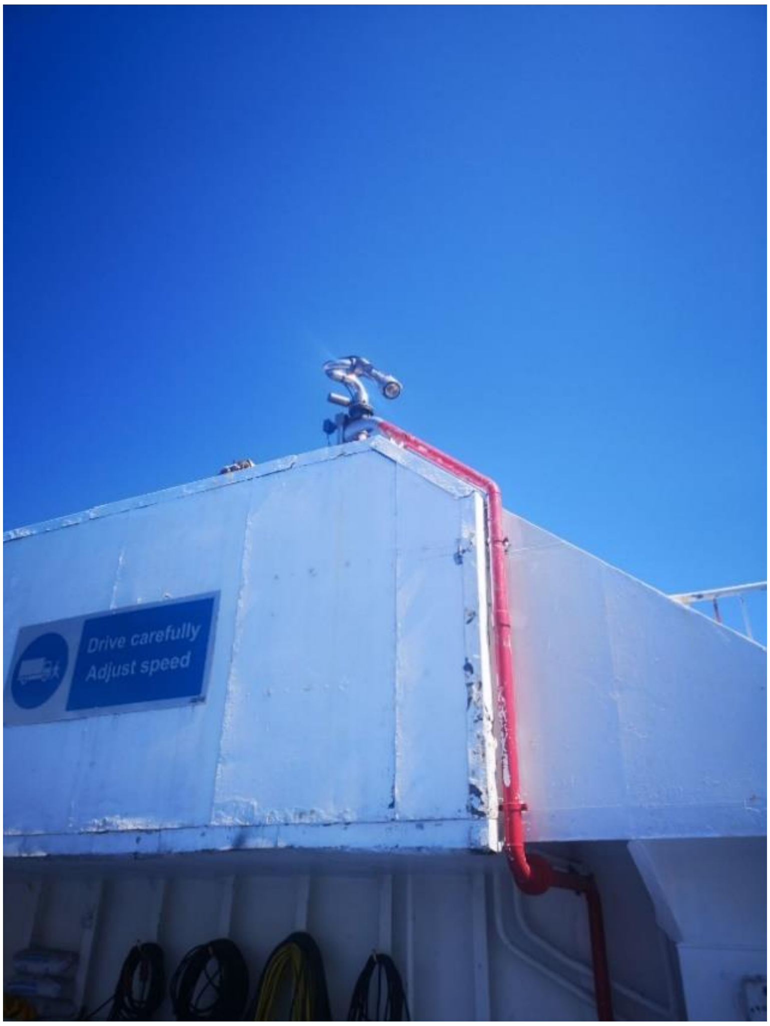


Figure 2. M/V Stena Gothica - Fire monitor 1

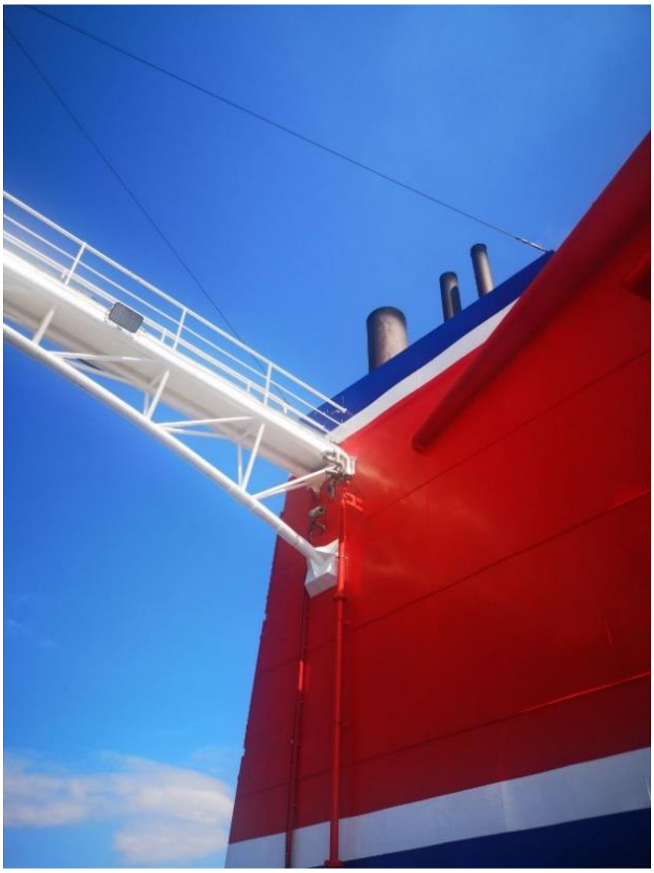


Figure 3. M/V Stena Gothica - Fire monitor 2

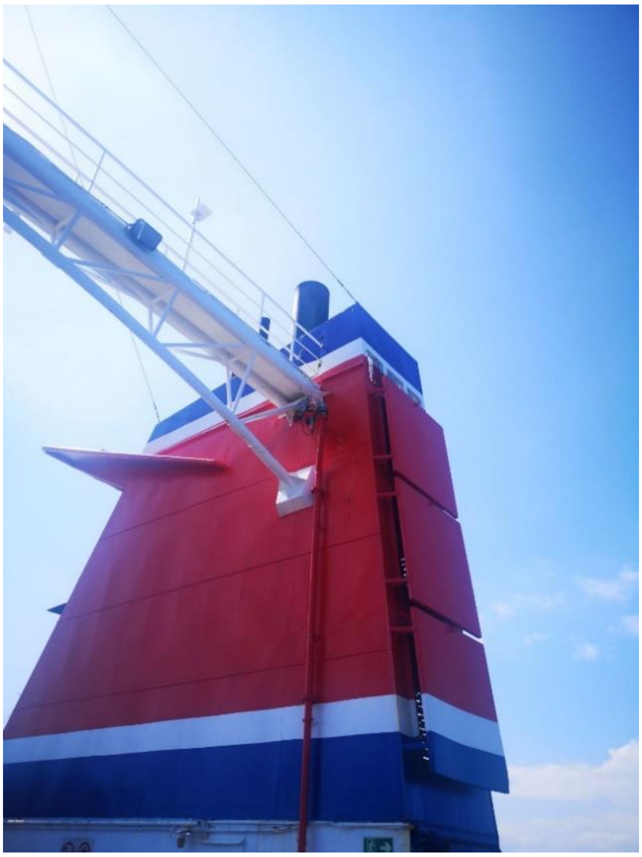


Figure 4. M/V Stena Gothica - Fire monitor

ANNEX I3 Fire curtain installation – examples

Boundary cooling nozzles installation examples at M/V Skåne and M/V Stena Jutlandica are illustrated on Figures below.

Figure 1. M/V Skåne - Boundary cooling nozzles installed on aft bulkhead of cabin deck above partial weather deck

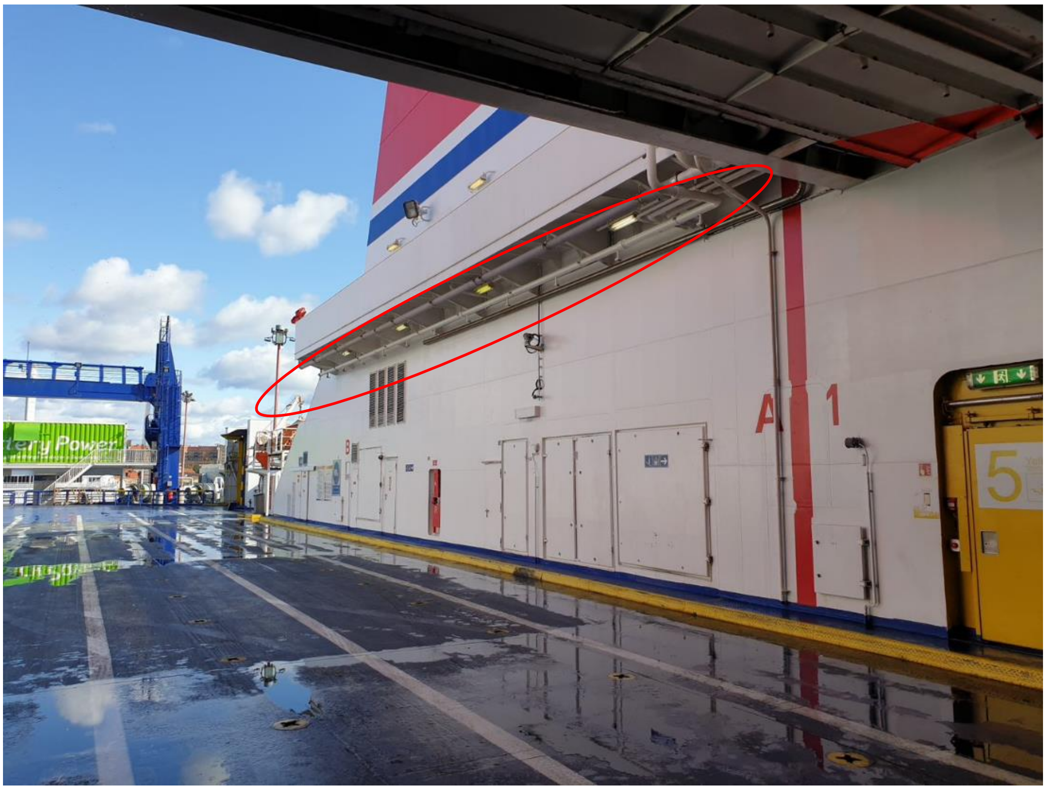


Figure 2. M/V Stena Jutlandica - Boundary bulkhead cooling nozzles installed on funnel/engine casing

ANNEX J

Annexes related to Action 11-C Ro-ro deck openings

ANNEX J1 Selected FIRESAFE I & II references

Please observe as a general comment that also discarded FIRESAFE investigations may be of interest for reference. Such material is often poorly documented, and it is recommended to seek advice from those involved.

Firesafe I

FIRESAFE: Study investigating cost effective measures for reducing the risk from fires on ro-ro passenger ships (FIRESAFE), EMSA/OP/01/2016

See below references to Firesafe I report:

Section 4.2.2 Rolling shutters
Section 4.2.8 Water wall
Section 4.2.11 Permanent closure of openings

Firesafe II Containment and evacuation

See below references to Firesafe II Containment and evacuation report:

Chapter 10 RISK CONTROL OPTIONS - CONTAINMENT

RCO Ban/closure of side & end openings

Chapter 11 RISK CONTROL OPTIONS – EVACUATION

RCO Closing all significant openings

RCO Closing all side openings

RCO Closing side openings near LSAs

Firesafe II Combined assessment

Reference to following RCOs, and their evaluation:

Det2	Ban / closure of side (PS & SB) openings (open ro-ro spaces)
Su3	Rolling shutters (PS & SB side) (Open ro-ro spaces)
Cont1	Ban/closure of side & end openings

as described in chapter 9.1.1.

Stena comments to EMSA on proposal to IMO SSE 7/6/1

With reference to FIRESAFE II study, closure of side opening and fwd/aft ends cannot be considered for existing vessels, for cost and technical feasibility reasons. FIRESAFE II FSA states that this action is not efficient for any vessel, new or existing, except, for Ferry RoPax newbuildings.

Statement on banning of side openings

It is an understandable proposal to eliminate side openings due to being root cause of several catastrophic events. However, the concept of open RoRo deck is an important enabler for certain types of vessels/operation by allowing for a certain DG types to be stowed on multiple decks onboard, instead of only on top/weather deck.

Example operation:

- Single vessel route operation and diverse cargo profile in combination with passengers
- High DG and reefer content in high volume operation.

Poor efficiency of new built vessels will extend life of existing tonnage, slowing down modernization of fleet.

In absence of open deck concept weather deck capacity must increase. Non passenger RoRos have already maximum weather deck area. Vessels with significant passenger facilities cannot in a natural way be redesigned with a top/weather deck for heavy cargo. This would have negative impact on stability, lashing forces, means of airlift evacuation and passenger experience.

Statement on closing fwd/aft ends of closed RoRo deck interfacing with weather decks

In light of a scenario to eliminate open RoRo decks the value of low located partial weather decks will increase further and efficiency of those being more important.

Closure of boundaries between closed & weather decks will complicate and prolong load operations and reduce capacities. It is also our opinion that such closure not to be mandatory at this point since no suitable technical solutions is yet identified as cost efficient or without imposing other risks when introduced. See FIRESAFE II comment on personnel safety and access for fire patrol and firefighting. There are however solutions at hand that need further investigation. Proposal is therefor to emphasize this subject in ongoing LASH FIRE and develop regulations accordingly.

It may be noted that the function of the closure is to be that of stopping air/oxygen supply rather than acting as fire/heat barrier. With such target, solutions may be found that will not jeopardize operations. At this point, the text “closed at both ends” may have alternative interpretations, spanning from permanent fixed structural closure to airflow barrier applied only in case of fire. Best way forward proposed to be clarified in coming investigations in LASH FIRE

Banning of side openings would be the largest risk reduction contribution for open roro decks. For further risk reduction, as alternative to also closing ends, other measures may be taken to reduce risk in same magnitude.

Stena Line comments to IMO SSE 7/6/1

This RCO has as isolated action good effectiveness but is not cost efficient and should not be implemented for following reasons:

1. RCO concluded inefficient by Firesafe FSA, which in turn was validated by IMO Expert Group.
2. Decreased capacity for dangerous goods and some special cargo
3. Ventilation system investment and space claim
4. Reefer electric connection installation, added risk, investment and operation cost.
5. Auxiliary power installation, negative environmental impact due to added fuel consumption operations cost and investment.
6. Added steel weight
7. No robust technical solution and installation so far available for closure of aft/forward openings.
8. Operational consequences from closure of end openings not investigated, will with no doubt lead to lost cargo capacity and dangerous goods space and added time in port.
9. Concepts for new buildings based on new rules not yet evaluated. Solutions could lead to adverse impact on stability, lashing forces and evacuation conditions.

Also following aspects to be considered:

10. Diversion of focus from operations and human elements to structural/system, despite that in case of for example Norman Atlantic, human elements are identified as dominant causes of failure.
11. More efficient to concentrate efforts to RCOs targeting early phase of fire development process rather than attempting to contain the uncontrolled full developed situation later. Would also give better message value: make sure to stop any risk development at early stage.
12. This action will give pay-back on open roro decks only, no other fire scenario
13. Closed RoRo decks have challenges of it own such as risk of smoke spread to public spaces and smoke exposure when manual action. Special case is toxic gases from electric battery car.
14. Poor efficiency of new built tonnage will slow down phase out of old tonnage, this will counter-act intentions of improved safety in fleet.

Proposed way forward:

Consider significant safety impact of remaining portfolio of actions from Circ 1615 and coming contributions from ongoing work.

Keep this RCO as a recommendation when operations so allow.

Await further investigations on this topic in ongoing projects.

ANNEX J2 Selected FIRESAFE I & II references

Figure1. Double ended ferry, superstructure on top of roro-deck open in both ends.

Figure 2. Double ended ferry, superstructure on top of roro-deck open in both ends. Small weather deck in each end.

Figure3. Typical Ro-Pax vessel with open roro deck with moderate number of openings, ending aft on a very small weather deck on each side of a centre casing.

Figure4. A vessel with an open roro deck with large number of openings. On top forward and aft weather decks with superstructure on top. Passage way is free under superstructure. Space under superstructure defined as open roro deck since open in both ends. Observe challenge to close these openings without obstructing efficient loading operations.

Figure 5. Roro vessel with a minor garage on forward part and a large weather deck.

Figure 6. Ro-Pax vessel with open ro-ro cargo space with side openings and opened to aft to a small weather deck on each side of a centre casing.

Figure7. Aft mooring openings is in this case the only opening on the roro deck above main deck. In this case openings are less than 10% of SB and BB surface and therefore this deck is not defined as "open roro deck".

Figure 8. Example of open ro-ro cargo space without weather deck aft, openings to mooring deck and aft end.

Figure 9. Example of a roro deck with no side openings ending open to a small weather deck.

Figure 10. Example of fully open aft end of the upper deck.

Figure 11. Example of double ender with hoistable car deck extending into both closed roro deck and weather deck.

Figure 12. Example of solution with upper deck open in both ends, and some few side openings.

Figure13. Example of open aft solution with shape of deck above that would influence the concept of any closing device.

Figure 14. Example of two level open roro decks.

ANNEX J3 Aft weather deck and opening samples

Figure 1. Example of aft opening, ramp down on port side, centre casing, and a small weather deck on starboard side

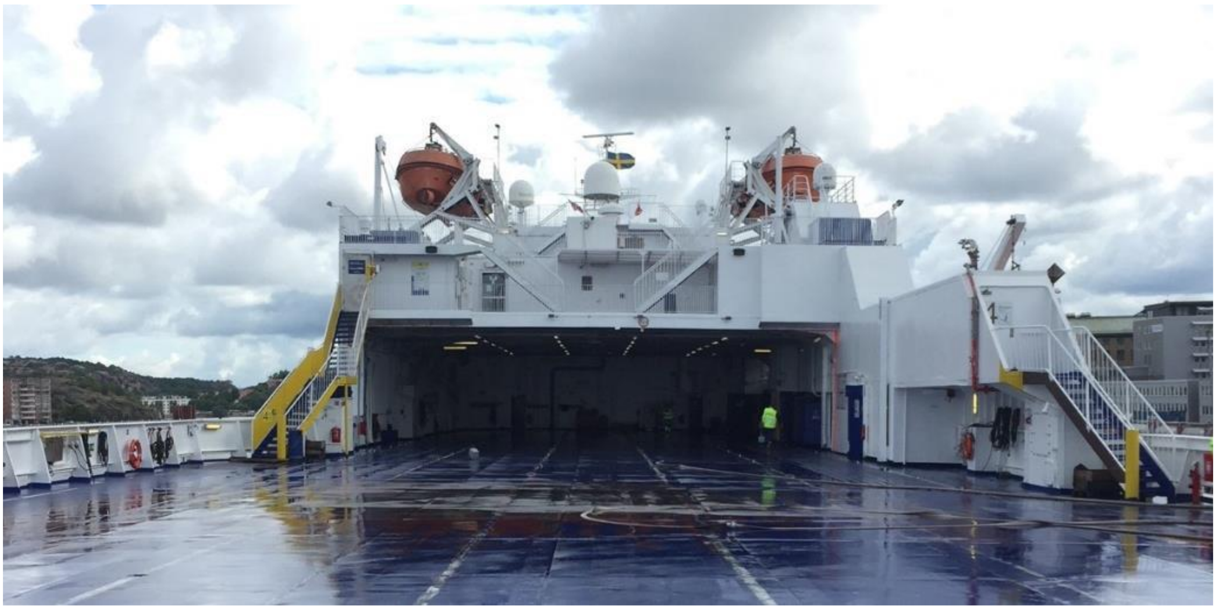


Figure 2. Example of a garage on forward part of upper deck.

Figure 3. Example of an aft end opening with complicated geometry.

Figure 4. Example of loading in way of aft opening. Illustrates the challenge to close such opening without disturbing loading operations or reduce capacity.

ANNEX K

Annexes related to Action 11-D Ro-ro space ventilation and smoke extraction

ANNEX K1 Weather deck types

Figure 1. Example of very sheltered weather deck, with high side plating

Figure 2. Example of very open unprotected weather deck

ANNEX K2 Example of instructions to drivers

Vehicle Deck Ventilation (Stena Europe)				
Version No. 1	Revision Date. 2019-02-07	Document ID. SOM-1708	Page. 1	Stena Line

SOM chapter: 7.2 **SMM reference: SMM-0060**

Validity: Stena Europe

All persons working on the vehicle decks shall be familiar with the provisions of chapter 32.3 of the Code of Safe Working Practices for Merchant Seamen. See appended copy.

Exhaust fumes on vehicle decks can be both unpleasant and potentially harmful if there is exposure to high levels of carbon monoxide and/or nitrogen oxide, see Code of Safe Working Practices for Merchant Seamen, Section 32.3.3., additionally petrol fumes pose a very serious fire risk. The Loading Officer must ensure that vehicle deck fans are operational at all times when cargo operations are taking place and also that ventilation is adequate whenever cargo is on board. It is the responsibility of the Loading Officer to ensure that vehicle deck fans are run at the correct settings.

In addition all vehicle deck staff should, where necessary,

a) remind drivers not to start their engines until required to do so.
b) report if the vehicle deck fans are not operating prior to loading and discharge and throughout both operations.
c) try to ensure that traffic continues to flow as smoothly as possible during loading and discharging so as to minimise the time vehicles are on decks with an engine running.

Should it become necessary, the Loading Officer may open the bow or stern door to produce a through draft whilst the vessel is secured in berth and on permission of the Master.

When bloodstock is being carried, it shall be ensured that ventilation is increased and adequate during the passage to what is normally set to dissipate residue fumes.

Vehicle deck fans on Stena Europe are started and stopped on Main Deck 3 forward or aft on the Centre Casing

ANNEX K3 Typical ventilation specification arrangement

37. Ventilation of Cargo Holds

371. Ventilation System for Cargo

The ventilation for the cargo holds consist of frequency controlled axial fans with a spark-free construction as per rules.

Motors are provided with stand still heating. Inlet cone with robust stainless steel safety net is provided. Silencers and other sound insulation measures to be provided in order to comply with design criteria's as specified in chapter 1. IP and Ex class as required by rules.

As far as practical the air velocity in the duct/distribution box not to exceed 10 m/s.

Where Acoustic insulation is required, rock wool or similar with stainless steel perforated plates shall be provided. Special care to be taken for the acoustical insulation of plenum located near public area.

Air change rate for empty holds according to rules. Minimum air change rate during loading/unloading 10 air changes/hour and 10 air changes/hour at sea. The ventilation systems will be designed for cargo loading from the stern and from the bow.

Description of cargo ventilation

Deck 1: Four (4) fans located forward of midship; two fans on port and and two fans on starboard side, will exhaust required air changes/hour to the lower hold in loading mode. Natural supply through open ramp cover.

Four (4) supply fans, located aft, will operate to ensure 10 air changes/hour in sea mode. Exhaust by the fans located in forward.

Deck 3: Four (4) reversible fans are located in the bow, and four (4) reversible fans are located in the stern. Fans in the opposite end of open ramp will exhaust air in loading condition. Natural air supply through open ramp. At sea fans in the stern are supplying fresh air. Exhaust by the fans located in forward.

Deck 5: Four (4) exhaust type fans are located in the bow. The fans will provide required air changes in loading condition and at sea. Natural air supply through open stern. System shall be functional also on bow loading condition.

Deck 7: Ventilation to be provided acc. to rules.

The final number of the all above cargo fans will be further considered during the following design steps.

Each loading scenario on each deck shall have a preprogrammed mode in the HVAC control system, based on the required number of air changes. Start and stop of the different modes and fans shall be possible from the cargo control room and the bridge.

Access is to be provided into and inside large and structural ducts and to fans/dampers. Fan take-out through gratings or openings with bolted plate. Lifting points for fan and motor removal to be provided.

Ventilation ducts are to be of ship structure, min. 5.0 mm steel plate painted according to the painting specification. Scuppers in ducts where needed for draining of water.

Air intakes are provided with demisters of hot dip galvanized steel are provided with louvres of hot galvanized steel. Inside of both is installed stainless steel net of size 10x10x1 mm.

Transfer air gratings of hot galvanized steel are provided for inlets and outlets on car decks. Area of outlet openings in holds is divided 2/3 in lower part and 1/3 in upper part. Lower hold will have ducts up under deck to comply with rules.

Cargo/vehicle deck fans to be controlled from Cargo Control Room, Wheelhouse and ECR.

Galvanised dampers have local mechanical position indication.

Fire dampers will be installed as per rules.

Starter cabinet for fans is located in a safe place outside car decks. Local switches and lights in the cabinet door. In case the starter cabinet is not in the vicinity of the fan, a separate safety switch for maintenance work is to be installed close to the fan. Starter cabinets are not allowed to be installed in CCR.

Figure 1. Fire damper arrangement on M/V Mecklenburg Vorpommern, in closed mode.