SAFETY and TRANSPORT

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RoBound – Ro-ro space boundary fire protection – Literature Study

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Summary

This is the report from the literature study of the RoBound (Ro-ro space Boundary fire protection) project. RoBound is carried out by RISE Research Institutes of Sweden AB.

The ro-ro ships have a large longitudinal space where cars, trucks and other cargo can be rolled on and rolled off. Despite improved fire protection regulations, many fire accidents have occurred on ro-ro ships and there are no signs of them diminishing in number or magnitude. During a review of the fire safety regulations, the IMO correspondence group has particularly pinpointed the need for additional experimental data or results of scientific studies regarding:

- The performance of A-60 boundaries in case of a ro-ro space fire, especially to prevent fire spread to accommodation spaces; and
- The performance of A-0 boundaries in case of a ro-ro space fire, especially to prevent fire spread between ro-ro spaces.

In this process, Sweden has moreover underlined the issue of the smoke tightness of A-class divisions with doors. While smoke tightness is a requirement for A-class divisions, the fire resistance test method in the Fire Test Procedures (FTP) Code is not designed to evaluate hazards associated with smoke spread. RoBound purpose is to clarify the performance of "state-of-the-art" fire boundaries between ro-ro spaces and accommodation spaces or other ro-ro spaces, and to give recommendations on how sufficient fire containment is ensured. RoBound aims to strengthen competence and influence regulation development regarding fire divisions of ro-ro ships.

The main result from the literature study is that :

- The concept of horizontal fire zones, allowing ro-ro spaces and special category spaces to be as long as the whole ship, was introduced in 1967 according to resolution A.122(V), but was made mandatory long time after. In SOLAS 1974, entered into force in 1980 the main vertical zones was included in the regulation.
- The land based method will not be used in RoBound since some smoke tightness solutions are based on an intumescent sealing joint. In order to be activated, the joint needs high temperature which is not reach in the land based standard.
- Hose ports, also denoted "Cat holes", are used on board with different experiences. Some think it works fine, other that it more problem. Level of maintenance vary from almost nothing to a lot of hassle. It is concluded that they reduce the amount of smoke spreading through the door compared with have a wedge and doorway open.
- Doors to the ro-ro space is not perceived as smoke tight, and so are not lift doors. Crew is aware of the importance of well closing fire doors, checks are made daily.
- Fire insulation in ro-ro spaces can be damaged by loading of trailers or during maintenance work. There can also be water damage (testing of drenchers, cleaning or by rain) and general wear and tear. Damaged insulation happens but not too often so it is not experienced as a problem for the crew.

1 Introduction

A ro-ro ship is a vessel onto which cargo, generally trucks and personal vehicles, can be rolled on and rolled off, and it is the most common type of vessel in Swedish waters. In the past decades, there have been many fires on ro-ro ships and a major challenge is smoke and fire spread. RoBound is a research project which aims to clarify how "state-of-the-art" in passive fire protection between ro-ro spaces and adjacent spaces affects fire and smoke spread, and on this basis make recommendations on appropriate improvements. This will be achieved through fire experiments, simulations, literature study of incident reports and regulations, and a workshop for identification of weaknesses and in collaboration with vessel operators, industry and authorities. Proposals for measures that contribute to a satisfactory and harmonized level of safety regarding the spread of smoke and fire will be prepared and communicated to the Swedish Transport Agency, for consideration to be forwarded to the IMO (International Maritime Organization). This report documents the literature study of the project, covering a review of relevant regulations and lessons learned from previous incidents. The report also document the workshop.

1.1 Background

Ro-ro ships have been an important component of the commercial maritime industry since their introduction in the 1940's. The ships have a large longitudinal space where cars, trucks and other cargo can be rolled on and rolled off. Despite improved fire protection regulations, many fire accidents have occurred on ro-ro ships and there are no signs of them diminishing in number or magnitude. This was a conclusion at the IMO [1] based on a statistical study of ship fires, which has led to an ongoing update of the international fire safety regulations for ro-ro ships in SOLAS Chapter II-2 [2] and associated codes. During a review of the fire safety regulations [1], the IMO correspondence group has particularly pinpointed the need for additional experimental data or results of scientific studies regarding:

- The performance of A-60 boundaries in case of a ro-ro space fire, especially to prevent fire spread to accommodation spaces; and
- The performance of A-0 boundaries in case of a ro-ro space fire, especially to prevent fire spread between ro-ro spaces.

In this process, Sweden has moreover underlined the issue of the smoke tightness of A-class divisions with doors. While smoke tightness is a requirement for A-class divisions, the fire resistance test method (for doors same as for bulkheads and decks) in the Fire Test Procedures (FTP) Code [3] (*Annex 1, part 3 – test for "A", "B" and "F" class divisions, sections 1-6*) is not designed to evaluate hazards associated with smoke spread. At the same time, prevention of smoke spread from a ro-ro space fire to the accommodation part of the ship is a difficult and significant problem on ro-ro ships.

1.2 Purpose and project goals

The purpose of the RoBound project is to clarify the performance of "state-of-the-art" fire boundaries between ro-ro spaces and accommodation spaces or other ro-ro spaces, and to give recommendations on how sufficient fire containment is ensured. The technical basis provided will support the revision of international IMO regulations and thus also the overall purpose to improve the independent management of fires on ro-ro ships.

RoBound aims to strengthen competence and influence regulation development regarding fire divisions of ro-ro ships.

A goal of the project is to write a guideline about the fire protection of ro-ro space boundaries. This guideline will be sent to Swedish Transport Agency, which is the Swedish Flag State and point of entry to the IMO.

2 Review of regulations concerning the fire integrity of ro-ro spaces

This chapter presents regulations concerning the fire integrity of ro-ro spaces. In this review, relevant regulations were considered to be international conventions and codes, national regulations as well as class rules and interpretations. These were reviewed with the aim to shed light on state-of-the-art and to provide a background for potential improvements.

2.1 Relevant regulations

- The regulation review was based on different official documents which are listed in .

Table 1. The list of relevant documents can be divided in two groups:

- Related to maritime application; and
- Related to land based application.

Table 1. The regulation review was based on the following documents

Maritime applications			**Land based applications**
IMO	**IACS**	**National Flag Administrations**	**European Standard**
SOLAS [2] Convention, as amended	IACS Blue book dated January 2019 [4]	Swedish Transport Agency [5]	EN 13501-2 [6]
2010 FTP Code [3], as amended			
MSC.1/Circ.1120 [7]			
MSC.1/Circ. 1615 [8]			

The concept of horizontal fire zones, allowing ro-ro spaces and special category spaces, was introduced in SOLAS 60 part H in 1967 according to resolution A.122(V), but it was never made mandatory and thus only applicable on a voluntary basis.

In 1974, SOLAS was modified to introduce the principle of horizontal fire zones into the Convention. This change was adopted in 1980 and based on three main fire protection principals:

- Structural fire protection;
- Fixed fire extinguishing system (“drencher”); and
- Fixed fire detection system.

Furthermore, a regulatory changes which had a large impact on the fire integrity of ro-ro spaces was the adoption of Res.MSC.338(91), in 2012 [9]. This resolution raises the fire integrity to A-30 for bulkheads and decks separating ro-ro and vehicle spaces onboard cargo ships and passenger ships carrying not more than 36 passengers.

2.1.1 Smoke tightness, FTP Code

The FTP Code [3] *(Annex 1, Part 3, Appendix 1)* requires the following regarding the integrity of the specimen, including doors:

> *§3.2:For all "A", "B" and "F" class divisions, including "A", "B" and "F" class doors, the following requirements shall be satisfied for the minimum test duration relevant to the classification (see paragraph 8.5 of appendix 1):*
>
> *.1 flaming: there shall be no flaming on the unexposed face;*

> *.2 cotton-wool pad: there shall be no ignition, i.e. flaming or glowing, of the cotton-wool pad when applied in accordance with paragraph 8.4.3 of appendix 1 or when used to assist evaluation of flaming (see paragraph 8.4.2 of appendix 1); and*
>
> *.3 gap gauges: it shall not be possible to enter the gap gauges into any opening in the specimen in the manner described in paragraph 8.4.4 of appendix 1.*
>
> *"A", "B" and "F" class doors are not required to be able to be opened or closed, during or after the specified test duration.*

In point 1 it is described that *there shall be no flaming on the unexposed side*, so the testing evaluates spread of flames to the adjacent compartment. The test does not evaluate the spread of smoke, unless the smoke could lead to ignition. This is further clarified in the following paragraphs of Annex 1, Part 3 in FTP Code:

> *§8.4.3.1: Tests with the cotton-wool pad are used to indicate whether cracks and openings in the test specimen are such that they could lead to the passage of hot gases sufficient to cause ignition of combustible materials.*
>
> *§8.4.6: Observations shall be made of the general behaviour of the specimen during the course of the test and notes concerning the phenomena such as cracking, melting or softening of the materials, spalling or charring, etc., of materials of construction of the test specimen shall be made. If quantities of smoke are emitted from the unexposed face this shall be noted in the report. However, the test is not designed to indicate the possible extent of hazard due to these factors.*

Hence, the test described for A-class divisions or doors of this class is not designed to evaluate hazards associated with smoke spread but only related to fire spread (including spread of smoke causing fire spread or ignition).

For land based building products there is, for the above-mentioned issue, a specific classification for smoke tightness for doors in a fire boundary, marked by the addition “-S”. This land based European Standard EN 13501-2 is described in the next section, see 2.1.2.

2.1.2 Smoke tightness, EN 13501-2

The European Standard EN 13501-2 *Fire classification of construction products and building elements – Part 2: Classification using data from fire resistance tests, excluding ventilation services* [6] is the standard used for land based doors regarding smoke tightness, or smoke leakage, defined in the standard as

> *ability of an element of construction to reduce the passage of hot and/or cold gases or smoke from one side of the element to the other to below specified levels.*

Smoke leakage can be classified, in this standard, in two cases. Either at ambient temperature only (denoted S_a) or at both ambient temperature and at 200 °C (denoted S_{200}). The performance criteria are defined as follows ([6] 7.5.6.3.1 *Smoke leakage*):

> *a) smoke leakage S_{200} - when the maximum leakage rate measured at both ambient*
>
> *temperature and 200 °C and up to a pressure of 50 Pa does not exceed 20 m^3/h for a single leaf doorset, or 30 m^3/h for a double leaf doorset;*
>
> *b) smoke leakage S_a - when the maximum leakage rate measured at ambient temperature, and at a pressure of up to 25 Pa only, does not exceed 3 m^3/h per metre length of gap between the fixed and moveable components of the doorset (e.g. between the door leaf and door frame), excluding leakage at the threshold.*

Fire doors and shutters are tested for integrity and the valuation of integrity shall be made on the basis of the following three aspects ([6] 7.5.9.3.2 *Integrity*):

a) cracks or openings in excess of given dimensions;

b) ignition of a cotton pad;

c) sustained flaming on the unexposed side.

These three aspects are, noted by the authors of this report, the same as in the criteria of the FTP Code, see section 2.1.1. It is also noted that the EN Standard has the criteria coupled to pressure which was not in the FTP Code.

2.2 Definitions and terminology

In order to understand clearly the regulations, some terms are particularly explained below.

According to SOLAS II-2/3, ro-ro space, special category space and vehicle space are defined as follows:

- §41: *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.*
- §46: *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.*
- §49: *Vehicle spaces are cargo spaces intended for carriage of motor vehicles with fuel in their tanks for their own propulsion.*

In other words, special category spaces are ro-ro spaces to which passengers have access, possibly during the voyage. These spaces are always “closed” ro-ro spaces and this is the most common type of ro-ro space on ro-ro passenger ships. Open ro-ro spaces are thus not be special category spaces.

Furthermore, SOLAS II-2/3 defines closed ro-ro spaces, open ro-ro spaces and weather deck as:

- §35 (§36): *Open ro-ro (vehicle) spaces are those ro-ro (vehicle) spaces which are 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.*
- §12 (§13): *Closed ro-ro (vehicle) spaces are ro-ro spaces which are neither open ro-ro spaces nor weather decks.*
- §50: *Weather deck is a deck which is completely exposed to the weather from above and from at least two sides.*

An additional description for weather deck is given in IACS UI SC 86 [5]:

- *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.*

Accommodation spaces are defined in SOLAS II-2/3 as:

- *1 "Accommodation spaces" are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, game and hobby rooms, barber shops, pantries containing no cooking appliances and similar spaces.*

Main vertical zones, also denoted MVZ, are defined in SOLAS II-2/3 as:

- *32 "Main vertical zones" are those sections into which the hull, superstructure and deckhouses are divided by "A" class divisions, the mean length and width of which on any deck does not in general exceed 40 m.*

The definition of fire integrity is specially described in section 2.3.2 in this report.

2.3 Requirements related to fire integrity of ro-ro spaces

The fire protection of ro-ro spaces is based on the general idea of fire containment, with the purpose to contain a fire in the space of origin. SOLAS applies specific fire containment requirements depending on the type of ship:

- Passenger ships carrying more than 36 passengers;
- Passenger ships carrying not more than 36 passengers; or
- Cargo ships other than tankers.

The fire integrity requirements for these types of ships are described below.

2.3.1 Principle of horizontal fire zones

Usually, passenger ships are divided into main vertical zones (MVZ) limited to 40 meters in length and can be extended to a maximum of 48 m (SOLAS II-2/9.2.2.1.2). These zones are thermal and structural divisions regarding the fire risks of the space. In ro-ro ships, ro-ro spaces are often longer than 40 meters, and in this view, SOLAS II-2/20.2.2.1 allows replacing the MVZ by main horizontal zones with the following description:

- *2.2.1 The basic principle underlying the provisions of this regulation is that the main vertical zoning required by 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 of a horizontal zone concept and by the provision of an efficient fixed fire-extinguishing system. Based on this concept, a horizontal zone for the purpose of this regulation may include special category spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.*

The required fire integrity of horizontal fire zones is shown in Table 2.

Table 2. Requirement of fire integrity of horizontal zones

Fire integrity/Type of ro-ro ship	Cargo ships	Passenger ships carrying more than 36 passengers	Passenger ships carrying not more than 36 passengers
Fire integrity required for horizontal fire zones	A-30	A-60*	A-0, A-30 or A-60, depending on the space on the other side: A-30** if accommodation space
Fire integrity required between ro-ro spaces within the same horizontal fire zone	A-30	A-0	A-30

*SOLAS II-2/9.6 states that the boundary bulkheads and decks of special category and ro-ro spaces shall be insulated to A-60 class standard. This applies for passenger ships carrying more than 36 passengers unless a category (5) open deck, (9) sanitary and (10) tanks and voids space is on one side of the division, then it can be reduced to A-0.

**The fire integrity can be reduced to A-0 if the two separated spaces are protected by an automatic sprinkler system (SOLAS II-2/9.2.2.4.2.3 and 9.2.2.4.2.3).

2.3.2 Definition of fire integrity, A-class

SOLAS II-2/3 defines the following for A-class divisions in §2:

> *"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.*

As stated in the last part, the fire integrity is defined by fire testing, as described in the FTP Code [3]. The FTP Code is intended for use when approving products for installation on ships, in accordance with the fire safety requirements of the SOLAS Convention [2].

SOLAS also define the B-class division and C-class division but this is not relevant in this study and is therefore left out.

2.3.3 Door in fire boundary

If a door is fitted in a ro-ro space boundary, it shall fulfil the same fire integrity requirements as the bulkhead it is fitted in and be tested according to FTP Code (SOLAS II-2/9.4.1.1.2). See section 2.1.1 in this report.

3 Review of accident investigations

Eleven accident investigation reports and one safety recommendation from fires in ro-ro spaces of ro-ro passenger ships have been studied. The fire accident reviews have been studied regarding spread of fire, spread of smoke and structural fire resistance (fire integrity). In this literature study the accident reviews are all referred to as “reports” (even if one of them are a recommendation).

3.1 Previous fire incidents in ro-ro spaces

The studied reports are publicly available and found on the Internet. The year when the ships were constructed are ranging from 1970 to 2009 and the accidents occurred between years 2003 and 2016. An overview of the reviewed fire accidents can be found in Table 3.

Table 3. Overview of the studied ro-ro ship fire investigation reports

Vessel	Year built	Year of accident	Fire spread (to other space)	Smoke spread (to other space)
Al Salam Boccaccio	1970	2006	Yes	Yes
Kriti II	1979	2012	Information missing	Information missing
URD	1981	2014	No	No
Amorella	1988	2005	No	Yes, to stairway
Stena Spirit	1988	2016	No	Yes
Joseph and Clara Smallwood	1989	2003	No	Yes
Pearl of Scandinavia	1989	2010	No	Yes, to accommodation
Mecklenburg Vorpommern	1996	2010	No	No
Commodore Clipper	1999	2010	No	Yes
Lisco Gloria	2002	2010	Yes	Yes, to accommodation
Norman Atlantic	2006	2014	Yes	Yes
Victoria Seaways	2009	2013	No	No

The table indicate that if there is fire spread, there is also smoke spread. In the following subsections 3.2.1, 3.2.2 and 3.2.3 are more details and findings regarding deficiencies and means for preventing fire spread, smoke spread and the ability of fire integrity presented.

3.2 Deficiencies and means to contain smoke and fire

The studied reports show different methods for controlling the fire and smoke from spreading, and also different deficiencies and reasons of why spreading occurred. In some of the reports, the construction is analysed and from Stena Spirit accident report it was concluded that the vessel did not meet the SOLAS requirements regarding fire protection. Findings from the study are presented in the sections below.

3.2.1 Fire spread

In three of the reports it was found that fire spread from the space of origin, whereas in eight cases the fire did not spread. In the 12th, no information on fire spread was found. In most of the accidents, the fire spread within the space of origin, to some extent, and this is fully accepted by SOLAS.

A method called boundary cooling is used on ships to lower the temperature on the unexposed side of a deck, to prevent combustible material from igniting from the heat caused by the fire on the other side. It is usually achieved by manually applying water on the unexposed surface but it can also be done using the drencher system. Here follow examples of reported boundary cooling in the studied reports.

"Were it not for the activation of the drenchers and the boundary cooling applied by the crew, it is highly likely that the heat would have ignited the tyres of the cars on the deck above and the fire would have developed on both decks." (Commodore Clipper)

"The 2/O (Captain Sheriff), together with the hotel crew, were cooling down the suspected areas in the accommodation with fire hoses as per master's orders, and it was always reported that there was no fire, that it was only smoke; the fire teams were trying to find and extinguish the fire moving from one location to the other." (Al Salam Boccaccio)

"They started to rig two fire hoses at 0319, and could see that the deck was very hot and starting to buckle. The initial flow of water from the hoses was described as being "steaming hot" and made the metal nozzles uncomfortably hot to hold."(Commodore Clipper)

Another way of actively preventing fire spread is by turning the ship in a favourable position, depending on the wind direction and location of fire. On Norman Atlantic, this was the only method helping the ship from not being entirely wrecked according to the investigation. This is a much later stage in the fire development, where the ship's hull should not collapse and the ship will sink. However, it can be used earlier in the fire development as well.

"The only effective action implemented to mitigate the fire effects was the intervention of the tugboats which moved the ship head to wind and cooled the hull with water, by preventing the vessel from being completely destroyed."

On the Commodore Clipper, the fire did not spread, and the vessel was able to return to port and remove trailers and trucks from the deck. This opportunity was well used and the analysis points out one of the problems of an accident in a ro-ro space, that it is hard to totally extinguish the fire even if all means are used.

"The fire was still contained by the combination of the drenchers and attacks from the firefighters, but it could not be completely extinguished without removing the trailers from the vehicle deck"

"This accident demonstrates that it is unlikely that even a moderate fire in a special category space will be extinguished while the vessel is at sea. It is therefore essential that the fire can be contained such that either an orderly evacuation can be conducted, or the vessel can continue to a port of refuge. This is the aim of the Safe Return to Port amendments to SOLAS. However, these apply only to vessels built after 2010 that are greater than 120m in length, or have more than three vertical zones; the majority of ro-ro passenger ferries currently trading will not be built to these standards."

3.2.2 Smoke spread

In eight of the reports, it was found that smoke spread from the space with the fire. In three of the cases, no spread of smoke was reported and in the last report, there was no information about smoke spread. In two cases, smoke was reported to spread to the accommodation parts of the ship. The range of smoke spread is described in different ways, for example smoke was *smelled* or smoke was *filling up a space*.

The cases where the smoke spread to accommodation were on the Lisco Gloria and on the Pearl of Scandinavia. On Lisco Gloria, it was probably spread of smoke because of an open door. On Pearl of Scandinavia the reason was not clearly described in the report but it could be interpreted that spread occurred through the ventilation system.

"The fire doors were closed by remote control from the bridge. A few minutes later, the ventilation was shut down in the entire ship. Due to smoke penetrating into the accommodation, the ventilation in the accommodation was turned on again at 06:07." (Pearl of Scandinavia)

A staircase can be the connection between a ro-ro space and accommodation or public space. As noted in the report from the fire accident onboard the Commodore Clipper, the smoke can spread through this "chimney like" space as a staircase can be.

"A staircase, known on board as the "green staircase," led all the way up from the starboard front corner of deck 3 to the restaurant. Fire gases from the vehicle deck had driven up the green stairs and started to make the atmosphere in the restaurant uncomfortable." (Commodore Clipper)

Ventilation can be one reason for smoke spread, even though the ro-ro space shall have separate system from other spaces. Shutting the ventilation system can be made from different locations and either manual or automatic. On the Commodore Clipper, the ventilation system was deactivated both manually and automatically.

"The chief engineer knew that the ventilation inlet dampers closed automatically, and he requested that the bridge team send someone to close the manual exhaust dampers at the aft end of the main vehicle deck. The off-watch second officer and a deck cadet went to the stern via the upper vehicle deck and, taking EEBD sets as a precaution, closed the dampers." (Commodore Clipper)

A way of active prevention of smoke spread is by turning the ship in a favourable position, depending on the wind direction and location of fire. This method was used on the Pearl of Scandinavia.

"The course was altered to prevent smoke passing over and along the ship. The speed was reduced to the lowest speed enabling the ship to keep its course." (Pearl of Scandinavia)

3.2.3 Fire integrity

A fire in a ro-ro space will heat the deck above by the flames direct having contact with the structure and by the hot smoke layer. Accordingly, the damages reported in the studied investigations are ranging from *small* to *severe* and *total loss* of the vessel. *Hot spots* are reported in four of the reports. On Lisco Gloria, where the fire started on deck 6, cooling of deck 7 was necessary for evacuation.

"At the starboard lifeboat, measures to cool the deck using a number of fire hoses began under the guidance of the second officer to make it possible for passengers to boar the lifeboat from deck 7."

Deck 7 was also reported as significantly discoloured and deformed by the investigation team. This was noticed where a hatch was located directly above the location of fire, and it was also noticed that there were no remains of A-60 fire insulation in the hatch after the fire.

In the investigation report of Lisco Gloria it is described how the fire zones were included in the design of the vessel.

"A-60 insulation ran between decks 2 and 4 over almost the entire length of the vessel (frames 60 to 239), between the main deck 4 and the garage area of the upper deck (frames 158 to 239), in the garage area of the upper deck to the cabins and lounges on deck 7, and between the accommodation decks 7 and 8."

When the ship was investigated, the insulation was largely destroyed on decks 4 and 6, after fires had been ongoing for weeks. On deck 2, there were no reported damages on the insulation and the fire had not spread to this deck.

According to the fire experts, temperatures must have risen to above 660 °C as the aluminium fitted in the superstructure melted. In spite of that, the A-60 insulation resisted the fire for an hour, even though the lifeboat station on the starboard side directly above the observed source of the fire had to be cooled down before it could be entered. However, the temperatures that occurred on the starboard side of deck 7 during the evacuation could still have easily been within the permissible approx. 200 °C (180 °C plus the estimated original temperature).

The above hence describes a problem where the A-class is fulfilled and functioning but where there are still other issues. In the above case the evacuation was disturbed and delayed due to hot spots.

Hot spots is a common occurred issue and boundary cooling seems to be a well-used routine for handling this. By cooling the deck above the seat of the fire, devastating damages can be reduced. This is, for example, noted in the report of Commodore Clipper where they also used a portable infra-red thermometer to record deck temperature. The deck between the main deck and the upper vehicle deck on Commodore Clipper were made of steel and complied with class A-0 (steel without thermal insulation).

"After about 30 minutes of drenching and boundary cooling, the chief and third engineers measured the temperature of the upper vehicle deck using a portable infra-red thermometer. They recorded average deck temperatures above the fire of 180 °C, and noted that the steel plating had buckled and the paint coating had gone. The heat did not cause any of the cars parked in the immediate area above the fire to ignite."

4 Identification of weakness in fire integrity

Chapters 2 and 3 form the basis for the workshop of *identification of weaknesses* in the fire integrity of ro-ro space boundaries that was carried out in the project webinar.

On Thursday June 11, 2020, starting at 9 am ending at 11 am, a webinar was held to identify and discuss weaknesses and measures regarding fire boundaries and doors in fire boundaries. This was done together with representatives from vessel operators, door manufacturer, thermal insulation company and Swedish Transport Agency. The participants was told to be prepared for the webinar by reading the draft of this report and thinking through the described issues together with questions specified in this chapter.

Section 4.1 is describing the main issues in the scope of this project.

4.1 Weakness in regulation

RoBound highlights problems in regulations regarding the

- Spread of smoke in A-class divisions; and
- Fire integrity between ro-ro space and accommodation space.

The following subsections explain the issues.

4.1.1 Spread of smoke in A-class divisions

While smoke tightness is a requirement for A-class divisions, the fire resistance test method in the FTP Code [3] is not designed to evaluate hazards associated with smoke spread.

Here follows the explanation of the issue in the relation between SOLAS and the FTP Code requirements:

- SOLAS II-2/3 defines that A-class divisions shall 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 140ºC above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180ºC 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.

Looking at point 4 in the definition above, it is described that the construction shall be *capable of preventing passage of smoke and flame* to the end of the fire test. For any A-class test, this means for 60 minutes of testing.

- The FTP Code, see Annex 1, Part 3, Appendix 1, described for A-class divisions or doors is not designed to evaluate hazards associated with smoke spread but only related to fire spread (including spread of smoke causing fire spread). This section of the FTP Code are detailed cited in section 2.1.1 in this report.

The problem with the conventional test (in accordance with FTP Code, Part 3) is that there is a neutral plane in the furnace, against which the test specimen (e.g. a door) is fitted. In the upper part of the door there will hence be an over pressure meanwhile that at the lower part, an under pressure. Thereby, a gap under the door (compare with SOLAS II-2/9.4.1.1.2) will seldom cause fire spread in a test, since primarily ambient air is here sucked into the furnace. In a real fire scenario it is although common with an over pressure over the whole door and smoke can spread through this gap. This is a big problem, both that A-class per definition requires smoke tightness but that this is not tested, and that some A-class doors may spread a lot of smoke in a real fire scenario.

To give the reader an idea of the cotton-wool pad and the gap gauges used in the FTP tests pictures are added showing such equipment from RISE's Fire laboratory facilities, where accredited FTP Code testing is carried out in Borås, Sweden.

Figure 1. Cotton-wool pad used for testing ignition (flaming or glowing) on the unexposed side. Size: 100*100*20 mm. 3-4 g of cotton

Figure 2. Gap gauges for measuring openings in tested specimen. 25 mm in diameter

Figure 3. Gap gauges for measuring cracks in tested specimen. 6 mm in diameter to move 150 mm in different directions of the crack.

4.1.2 Fire integrity between ro-ro space and accommodation space

Another issue in regulations concerns the fire integrity required on horizontal fire zones. For passenger ships carrying more than 36 passengers it is required to be A-60 (SOLAS II-2/20.5) whereas in passenger ships carrying not more than 36 passengers (SOLAS II-2/9) the fire integrity requirement is A-30.

The reader are proposed to look at Table 2, section 2.3.1, and compare the requirement of the fire integrity of different ship types and spaces. Note that there is a difference in fire integrity depending on the number of passengers and the type of ship.

- SOLAS Chapter II-2 has the following fire safety objectives defined in regulation 2:

  §1.1 The fire safety objectives of this chapter are to:

  .1 prevent the occurrence of fire and explosion;

  .2 reduce the risk to life caused by fire;

.3 reduce the risk of damage caused by fire to the ship, its cargo and the environment;

.4 contain, control and suppress fire and explosion in the compartment of origin; and

.5 provide adequate and readily accessible means of escape for passengers and crew.

- The objectives are achieved by fulfilling the functional requirements in the regulation. SOLAS has the following functional requirements defined in Chapter II-2/2:

  §2.1 In order to achieve the fire safety objectives set out in paragraph 1 above, the following functional requirements are embodied in the regulations of this chapter as appropriate:

  .1 division of the ship into main vertical and horizontal zones by thermal and structural boundaries;

  .2 separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries;

  .3 restricted use of combustible materials;

  .4 detection of any fire in the zone of origin;

  .5 containment and extinction of any fire in the space of origin;

  .6 protection of means of escape and access for fire-fighting;

  .7 ready availability of fire-extinguishing appliances; and

  .8 minimization of possibility of ignition of flammable cargo vapour.

Hence, this is the same objective and functional requirements independent of type of ship or number of passengers and it is not clear why there is a difference in fire integrity of horizontal zones.

4.2 Preparation for the webinar

The main goal with the webinar was to identify weaknesses in the fire integrity of ro-ro space boundaries, with the help of the participants. The webinar was introduced with a review of the literature study, as documented in this report. Then an open discussion about the formulated issues began with the participants sharing their experiences and opinions in the topics. In order to prepare the webinar, a list of questions was been distributed to the participants and are seen in section 4.2.1.

4.2.1 Discussion/ questions to the participants prior the webinar

Below are questions asked to the participants prior to the webinar:

- What are sufficient requirement of safety measures of doors in fire boundary?
- Why is there a difference in fire integrity depending on the number of passengers?
- What is your experience of smoke spread during an fire-fighting operation into the ro-ro space – does crew know what doors are “safe” to use, without risking smoke filling of the accommodation part of the ship?
- Have you any experience in smoke/fire spread (from ro-ro spaces)?
- How does it look onboard regarding insulation, penetrations and seals in A-class division between ro-ro space and accommodation spaces – any experience in higher requirements than SOLAS?
- Your experience of lack of maintenance in fire boundaries? Are there cracks and gaps?
- Your view of horizontally A-class division between ro-ro space and ro-ro space?

- Have you any experience with double-doors/air lock? are there small stair case fans and are they sufficient for ventilating smoke/preventing smoke spread?
- How efficient is boundary cooling? Takes at least two(?) crew members…Is it a solution to thicken the insulation? To use the drencher? Increase the classification of boundaries?

It would also be interesting to discuss the introduction of different safety measures. What are your thoughts about the following:

- Air locks/Gates (double doors) in passage to stair case
- Hatch/fan in top of stair case to extract smoke
- Under pressure/over pressure between the ro-ro space and the accommodation
- Overpressure in stair case
- Hole for hose, "cat holes"
- Other?

Is any of this already used onboard – any experience?

4.3 Results of the webinar

The webinar resulted in discussions and proposed solutions. The participants gave their personal experience and opinions in the different issues and topics. In this section the results of the webinar is documented.

Moreover, a questionnaire has been sent to some chief engineers on vessel from the participated ship owners. Results of this questionnaire are presented here together with webinar results.

The results are presented below and split into the two main subjects which are doors and smoke tightness and integrity and insulation.

4.3.1 Doors and smoke tightness

Regarding smoke tightness of doors the following comments was noted:

- Sliding doors to the ro-ro space in reality is not perceived as smoke tight, and so are not lift doors.
- Smoke tightness is important also in everyday use of the vessel since any smell can cause anxiety with the passengers.
- Crew is aware of the importance of well closing fire doors and checks are made daily.

Discussion regarding doors to/from ro-ro space included the aspects presented below:

- Sliding doors are very well used and a lot of maintenance is made. Sliding doors have more "problems" and need more maintenance than hinged doors.
- The amount of maintenance required varies considerably and even after the correct fitting and setting up, sliding doors require continuous small maintenance.
- It is more complex to fulfil requirements for sliding doors than hinged doors, from the supplier point of view.
- The closing mechanism is the main point of weakness. It is fairly common that the closing of doors are malfunctioning and maintenance is needed to keep them well running and closing. This is primarily for sliding doors.
- The doors shall be able to close also when boat is leaning.
- Corrosion and moisture can be a problem for doors on car decks and doors have been replaced by new.

Hose ports is one part of not spreading more smoke than necessary through open doors, when fighting a fire. Hose ports can also be mentioned “cat holes”, since they are like the opening for cats you can see in doors to private homes. The hose ports are used to let the hose pass through a small hole instead of running through a door slip. Hose ports are a requirement in SOLAS II-2/9.4.1.1.8:

> *4.1.1.8 Except for watertight doors, weathertight doors (semi- watertight doors), doors leading to the open deck and doors which need to be reasonably gastight, all "A" class doors located in stairways, public spaces and main vertical zone bulkheads in escape routes shall be equipped with a self-closing hose port of material, construction and fire resistance which is equivalent to the door into which it is fitted, and shall be a 150 mm square clear opening with the door closed and shall be inset into the lower edge of the door, opposite the door hinges or, in the case of sliding doors, nearest the opening.*

Regarding these hose ports it was both positive and negative arguments, see notes below:

- “Cat holes” are used on board with different experiences. Some think it works fine, other that it more problem and they prefer wedge and open doorway. Level of maintenance vary from almost nothing to a lot of hassle.
- Problems with “cat holes” mentioned are
  - corrosion,
  - that closing is not working,
  - that it is only possible using it in one direction, and
  - that it is not easy to use.
- Positive with “cat holes” are
  - that the fire team can advance through the vessel, and
  - that it help controlling the smoke spread through the door.
- Hose ports in doors are used both in sliding doors and in hinged doors.

Regarding safe approach and how to use the doors in case of fire on ro-ro deck:

- It depends on the situation relays on the fire chief's situation assessment, and
- It was mentioned that smoke spread quickly when doors are open, which was experienced in fire drills onboard.

Solutions discussed:

- No experience in air locks, but doors in top of the staircase that is closed and locked during voyage works.
- Keep the sliding door in everyday use, put a hinged fire door behind that sliding door that will close upon alarm.
- Lead the evacuation to the outside of the ship and not to the middle, so these doors to ro-ro space not need to be used.
- Install intumescent list for smoke tightness.
- No experience of smoke extraction systems on the participating ships. Smoke extraction system can be seen as risky since extraction of smoke will possible let in fresh air, which might not be good for fire development. Besides, atriums have the requirement of smoke extraction system in passenger ships (SOLAS II-2/5.5) and Japan is discussing smoke extraction in IMO subcommittee.

As future work it was suggested:

- To study used doors and their function and fire rating after a lot of years.

4.3.2 Integrity and insulation

This part of the webinar started with showing some pre-result from CFD simulations in the project. The simulations of fires on ro-ro spaces (open and closed) are done order to monitor the reaction of the fire insulation. As a first glance, the ISO fire curve may not be realistic to use for the classification of fire integrity in ro-ro spaces.

Discussion regarding insulation included the following aspects:

- Fire insulation in ro-ro spaces can be damaged by loading of trailers or during maintenance work. There can also be water damage (testing of drenchers, cleaning or by rain) and general wear and tear.
- Damaged insulation happens but not too often so it seems not to be a problem.
- Wet insulation need to dry to have full function and this might be hard to fulfil on ro-ro ships.
- Insulation will last at least 50 years, but need to be free from scratches, dirt and such. Normally thin aluminium or a plate is used as cover for the insulation on board.
- The machinery spaces on board are more tidy than ro-ro spaces. It is almost impossible, at a practical level, to eliminate all damage but it should be dealt with as soon as it is reported.
- Small repairs can be done by the ship staff while in service. Large repairs will be carried out by an outside contractor. This can be done in stages while the ship is in service or in drydock/layover.
- In some ships they have sprayed insulation instead of insulation boards. The sprayed is experienced as more difficult to repair and restore after doing work behind. Sprayed insulation is cheaper to install than boards.
- The higher fire rating the thicker insulation, the insulation companies work on thinner and lighter material but normally thicker is available on the market so far.
- Approved sealant, flanged or Brattberger are used for penetrations. These are generally available and can be sourced easily.

Discussion regarding integrity included the following aspects:

- Integrity of ro-ro space boundaries will not likely be more than A-60 in the IMO discussions as it sounds like now.
- The difference in fire rating is probably the that the more lives the vessel care about – the higher rating in fire integrity.
- Discussion about alternative powered vehicles (APV) and that it might result in point load of heat and more hot spots in the future fires, which may be an argument for higher fire rating.

Solutions discussed:

- Fire blanket for cars are used in fire drills (not any real fire yet) on one vessel. These blankets are 9*6 m and so far appreciated by the crew during fire drills.
- Over-pressure in accommodation is common among the operators and this together with doors keep the smoke spread to a minimum, is the experience from some ships.

As future work it was suggested:

- Impact of fire boundaries for ships with alternative power system

4.3.3 Questions and answers

Why not testing according to the land based standard for smoke tightness in buildings, EN 13501-2?

The main problem of the testing according to the land based standard (EN 13501-2) is that the maximum temperature of tests is 200°C. Some smoke tightness solutions are based on an intumescent sealing joint. In order to be activated, the joint needs high temperature which is not reach in the land based standard.

4.3.4 Pictures

In this section some pictures of discussed topics are shown.

Figure 4 Example of damaged fire insulation

Figure 5 Example of undamaged insulation

Figure 6 Example of “cat hole” in hinged door

Figure 7 Example of “cat hole” in sliding door

5 Conclusion

The concept of horizontal fire zones, allowing ro-ro spaces and special category spaces to be as long as the whole ship, was introduced in 1967 according to resolution A.122(V), but was made mandatory long time after. In SOLAS 1974, entered into force in 1980 the main vertical zones was included in the regulation.

FTP Code are using the same test evaluation for doors as for bulkheads and decks regarding fire integrity. This test does not evaluate the spread of smoke. In the land based testing standard, the same evaluation methods (gap gauges, cotton pad and sustained flaming on unexposed side) are used and the doors are tested either for ambient smoke (20 ℃) or for both ambient and hot (200 ℃) smoke. This land based method will not be used in RoBound since some smoke tightness solutions are based on an intumescent sealing joint. In order to be activated, the joint needs high temperature which is not reach in the land based standard.

Fire integrity requirements in SOLAS varies depending on ship type and number of passengers even if the purpose of the SOLAS regulation and the functional requirements are the same, to contain fire in the space of origin.

Investigation reports indicate problems with extinguishing a fire in a ro-ro space without unloading the vehicles first. Even if the fire protection systems works well and the crew actively fight the fire by all means, one investigation made it clear it did not extinguish the fire until the ship was in port and could un load the cargo.

Hot spots are frequently occurred when there is a fire in ro-ro space. A hot spot is when the steel above the seat of fire very hot and water from either fire mains or drencher are used to cool down the surface. This method is called boundary cooling and takes resources from crew keeping the surface cooled.

Hose ports, also denoted “Cat holes”, are used on board with different experiences. Some think it works fine, other that it more problem. Level of maintenance vary from almost nothing to a lot of hassle. It is concluded that they reduce the amount of smoke spreading through the door compared with have a wedge and doorway open.

Doors to the ro-ro space is not perceived as smoke tight, and so are not lift doors. Crew is aware of the importance of well closing fire doors, checks are made daily. Sliding doors are very well used and a lot of maintenance is made. Sliding doors have more “problems” and need more maintenance than hinged doors.

Fire insulation in ro-ro spaces can be damaged by loading of trailers or during maintenance work. There can also be water damage (testing of drenchers, cleaning or by rain) and general wear and tear. Damaged insulation happens but not too often so it seems not to be a problem for the crew.

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