DNV·GL

FIRES ON RO-RO DECKS

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ABBREVIATIONS

Alternative-fuel vehicle (AFV): A vehicle that runs on a fuel other than traditional petroleum fuels (petrol or diesel fuel), such as electric cars, hybrid electric vehicles, hydrogen, LNG and LPG

CCTV: Closed-circuit television (also known as video surveillance)

Deluge system: A fixed water-based fixed fire extinguishing system employing open nozzles attached to a piping system connected to a water supply. Release is initiated by opening the section control valve

Open Ro-Ro spaces are those Ro-Ro spaces that 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 (SOLAS Ch. II-2 Reg.3.35)

Vehicle carrier means a cargo ship with multi deck Ro-Ro spaces designed for the carriage of empty cars and trucks as cargo (SOLAS Ch. II-2 Reg.3.56 – the new amendment). This includes PCC (pure car carriers) and PCTC (pure car and truck carriers), which are terms frequently used by the industry

RoPax: Ro-ro passenger ship (passenger ferry)

Ro-ro spaces: In this context, this will include both open and closed Ro-Ro and special-category spaces (Ro-Ro spaces on RoPax vessels)

Weather deck is a deck which is completely exposed to the weather from above and from at least two sides (SOLAS Ch. II-2 Reg.3.50)

1 INTRODUCTION

There have been several serious fires in Ro-Ro spaces recent years and how to address this has been discussed in length. We issued a paper in 2005 (paper 2005-P018 identifying 25 fires within Ro-Ro spaces) and due to the ongoing debate we found it useful to revisit the paper and study recent fires (2005 – 2016) as well as considering impact of new rules and "new" cargoes represented by alternative-fuel vehicles.

It should be noted that engine room fires is a notable risk also for RoPax, vehicle and general Ro-Ro vessels, in this paper we will however only address fires within Ro-Ro spaces.

It is difficult to extract information from the various fire cases and some of the entries could not be completely confirmed. In particular time of events can be an estimate, but the overall conclusions should, taking all 35 fires into account, be rather robust. We would invite all to provide corrections or amendments if it is found that we have misunderstood the events for a particular fire.

We do in particular appreciate the detailed reports issued by Denmark, Japan, Germany and UK which where useful for our work.

It is important to note that a positive trend last 11 years is no guarantee for successful operations in the future or vice versa. This report reflects the findings of recent fires and only our recommendations in Ch.6 reflect our policy on the subject.

2. FIRES IN RO-RO CARGO SPACES 2005–2016

Only vessels complying with the SOLAS convention or domestic ferries assumed to be substantially in compliance with this standard are considered. The analysis has divided fires into three categories:

- RoPax vessels
- Vehicle carriers
- General Ro-Ro cargo vessels

This categorization is based on regulations, intended cargo, trade pattern, arrangement of cargo hold and the type of fixed fire-extinguishing system provided for the Ro-Ro spaces.

By using international databases, class records, EMSA marine casualty reports, incident reports and interviewing owners, we have identified 35 fires within Ro-Ro spaces between 2005 and 2016. In our previous paper on the subject, we identified 25 fires within Ro-Ro spaces between 1990 and 2003. The difference can be explained by better reporting and a larger fleet, but it should be noted that fires on cargo ship dominated from 1990 to 2003, whereas there are now (2005–2016) relatively more fires on RoPax vessels.

2.1 RoPax vessels

Eighteen fires on Ro-Ro decks were identified between 2005 and 2016; a summary can be found in Annex 1.

Assuming a fleet of 750 RoPax above 4.000grt , this represents 2.0 x 10^{-3} fires per ship-year. Five of these fires caused major damages, abandonment of the vessel and even injuries or fatalities, amounting to 0.56 x 10^{-3} cases per ship-year. This is a rather high number, and is therefore a risk that should be looked into.

The main findings are:

a. The RoPax vessels considered are in general rather new vessels. Only two RoPax in these files were built prior to the introduction of the SOLAS '74 Convention (built 1979, 1980), whereas three were built in the 1980s (1986, 1988 and 1989). None of these were among those having a major fire.
b. The vessels are rather large, all having a gross tonnage above 10.000 grt with the resources of available power, space and firefighting capacity associated with large RoPax vessels.
c. In all cases, the fire was caused by the cargo or the power connection between reefer unit and the vessel.
d. Failures in reefer unit or power connection serving these units are the most frequent cause and the probable cause for at least four of the five major fires. Other causes include electrical systems in cars, buses and lorries, as well as fires originating in cargo in lorries (including transported used vehicles).
e. Three of the fires resulted in a total loss of the vessel, all three being an open Ro-Ro space design. There are two cases defined as a major fire; these have a closed Ro-Ro space.
f. The use of the fixed fire-extinguishing system played an important role in fires causing major damages. In two cases, the water was not discharged onto the deck on fire (Norman Atlantic and Lisco Gloria); in another, the release was delayed for 25 minutes (Commodore). Data for the Sorrento and Sunflower Daisetsu is not yet available.
g. The "successful" cases are due to rapid response (applying the deluge system quickly or fast approach by the fire team, sometimes combined with discharge of cargo when entering the port).

2.2 Cargo Ro-Ro vessels

Eight fires on Ro-Ro decks were identified between 2005 and 2016; a summary can be found in Annex 2.

Assuming a fleet of 560 general Ro-Ro vessels above 4.000 grt, this represents 1.19 x 10^{-3} fires per ship-year. One of these fires was considered as a total loss, whereas one vessel did not return into service (assumedly due to age of vessel and market situation). The major fire rate is therefore 0.30 x 10^{-3} fires per ship-year.

The main findings are:

a. The cause of the fire was only defined for three of the cases, two being shift of cargo in adverse weather, and the third having originated in cargo stowed on the Ro-Ro deck.
b. Cargo Ro-Ro vessels may have a deluge system or CO_2 for protection of the cargo holds. The total loss could be explained by the fact that the deluge system could not be operated. There is no data yet for the vessel which did not return into service.
c. In one incident, the CO_2 was successfully applied within 15 minutes. This demonstrates that even CO_2 systems can be released in a quick and safe manner if crew are prepared for that task. The damages in this case were rather limited.
d. There were two major fires on a weather deck which lasted for several hours. However, the vessels were not total losses (one with only moderate structural damages), presumably since most of the smoke and heat were dispersed by the wind.

2.3 Vehicle carriers

Nine fires on Ro-Ro decks were identified between 2005 and 2016; a summary can be found in Annex 3.

Assuming a fleet of 825 vehicle carriers above 4.000 grt, this represents 0.91 fires x 10-3 fires per ship-year. Three of these fires caused major structural damages, and there was one fatality due to release of CO_2. The major fire rate is consequently 0.40 x 10-3 fires per ship-year. There were no total losses, whereas one ship did not return into service (assumedly due to age of vessel and market situation).

The main findings are:

a. The cause of the fire was only defined for two of the cases, one being within a new car (probably the electric system), and the other due to shift of cargo in adverse weather.
b. All vessels are large, from 38.000 to 71.000 grt, each with a capacity of several thousand cars. The risk for an ignition for each unit (cargo is predominantly new cars) is very low.
c. Time to release of the fixed fire-extinguishing system (CO_2 in all these cases) was typically 20 minutes, which is not longer than that seen for many RoPax vessels protected by a deluge system.
d. One fire reignited two days later when cargo was opened in a controlled way (the new fire was therefore quickly brought under control).
e. In several cases, the damages to structure were not severe – maybe due to the restricted ventilation conditions (these vessels typically have closed cargo holds).
f. The damage to the cargo (predominantly new cars) represents a significant cost in some of the cases.

3. FIRES, CASES

3.1 Sources of ignition

The source of ignition is not identified for all of these cases. Often this requires a careful and costly investigation which needs to be funded. Reports do not always confirm definitively the source, and we have used the most likely source or the best estimate when this is identified. If inconclusive or only rumours, we have not recorded any entry for that fire case.

The causes were identified as follows:

Cause	RoPax	Cargo Ro-Ro	Vehicle carriers	Total
Buses, trucks (not their cargo)	2	0	0	2
Cars (other than new)	2	1	2	5
New cars	-	0	1	1
Other vehicles (type not identified)	0	1	0	1
Cargo on trucks (incl. transported vehicles)	5	0	0	5
Reefer unit	4	0	0	4
Un-authorized charging of electric car	1	0	0	1
Shifting of cargo due to adverse weather	0	2	1	3
Unknown	4	4	6	14
Total, all entries	**18**	**8**	**9**	**35**

Calculating per vehicle, we can conclude that the risk for a fire staring in a vehicle, and in particular a new vehicle, is very low; there are only nine confirmed cases for the period considered. Taking into account the number of vehicles carried on a Ro-Ro ship, we need still to take this hazard into consideration. Given the low frequency per vehicle, it is a challenge to propose measures (screening of vessels before loading, etc.) that will significantly reduce the risk of fire, except for the three elements detailed in the next paragraphs.

There are, in addition to the above-mentioned vehicle fires, two cases where vehicles caught fire when carried as cargo (one minibus and one car). Transported units represent typically a small fraction of the total number of vehicles transported by Ro-Ro vessels – this implies that these items may have a higher frequency. Old transported vehicles should therefore be screened before being allowed on board (general condition, amount of fuel, etc.).

Reefer units (electric powered or diesel driven) are not carried on all Ro-Ro ships. Further, if carried they will also represent a small number compared to all other vehicles carried on board. Using RoPax as an example, we have as many reefer fires as vehicle fires. The risk per unit is consequently considerably higher for reefer units than vehicles. Further, when noting that several of these reefer fires were severe, we will consider the reefers as an obvious candidate when weighing items that should be addressed if we intend to improve the fire safety level on board RoPax vessels.

Shift of cargo represents, at least for cargo Ro-Ro and vehicle carriers, a notable source of fires (10–20%). Improved cargo securing and weather routing could have prevented some of these fires.

There is one entry with "un-authorized charging of rebuilt electric car" (Pearl of Scandinavia). This is considered as a special case, and we will not make any conclusions based on this, except for some operational recommendations put forward in section 6.

There have been rumours about fires starting due to truck drivers or passenger making food on Ro-Ro spaces. The risk of stowaways has also been debated. No confirmed cases, though, have been identified.

Accumulation of gases leaking from fuel tanks of vehicles and the possible ignition of these by ventilation fans or unprotected electrical equipment has been considered as a risk. This is also addressed by SOLAS with requirements for ventilation rates, ex-rating of extraction fans and protection of electrical equipment. No such cases have been identified in this paper (35 fires) or our previous paper (25 fires).

3.2 Arrangement of Ro-Ro spaces

There are, in general, three types of Ro-Ro spaces on board these vessels:

- Closed Ro-Ro spaces
- Open Ro-Ro decks (openings are typically aft and in sides, but not above)
- Open Ro-Ro decks/weather deck type (open decks with no deck above Ro-Ro lanes)

All of the four total losses with three RoPaxes (Norman Atlantic, Sorrento and Lisco Gloria) and one general Ro-Ro (UND Adriyatik) were of the open Ro-Ro space type. The open Ro-Ro spaces represent challenges with regard to fire scenario, as we have here well-ventilated fire under a tight steel deck which reflects heat and accumulates fire gases. There are also notable challenges with regard to escape ways, location of life-saving appliances and air intake to the engine room and emergency generator, which can be contaminated and damaged by smoke and flames emerging from openings provided in the side of the Ro-Ro spaces. We can, however, safely assume that the situation for the total losses would have been far better if the fixed fire-extinguishing system, which was deluge in all four cases, had operated properly (data for the Sorrento is pending, and preliminary statements suggest that deluge was released here).

There are three other vessels which did not return to service due to the combination of damages, age of vessel and market situation (one general Ro-Ro being 22 years old, two vehicle carriers being 24 and 28 years old). At least two of these fires were within a closed cargo hold. The fire damages for these vessels are considered to be far less severe than the four total losses.

We have identified two fires on weather decks (the general Ro-Ro vessels 2013.C1 and 2005.C1 – see Annex 2). Both fires were massive, and at least one involved large quantities of fuel. There were certainly structural damages to both vessels, but a critical situation was brought under control. We can predict that a similar fire on an open Ro-Ro space would be more difficult to handle.

The majority of the remaining cases were on closed Ro-Ro decks, and these were extinguished by the fixed fire-extinguishing system (CO_2 or deluge), in combination with use of fire teams and, in several cases, after vehicles were unloaded in port.

3.3 Performance of deluge systems

All closed and open Ro-Ro spaces shall be protected by a fixed fire-extinguishing system. This is either a deluge (water mist recently developed as an alternative), CO_2 or, in some cases, a high-expansion foam system.

Deluge systems shall be provided for closed and open Ro-Ro cargo spaces on RoPax vessels. CO_2 is not an option for these vessels. Cargo Ro-Ro and vehicle carriers shall use a deluge system for Ro-Ro spaces that cannot be sealed, and they can even use this option for closed Ro-Ro spaces (CO_2 being an alternative for that category).

The deluge system usually discharges seawater, which may cause some inconvenience if unintentionally released upon vehicles. Further, the release is initiated from a deluge control station, often located at a distance from wheelhouse, engine control room and crew accommodation. It is not necessary to shut down ventilation (fans and dampers) prior to releasing the deluge, although the performance of the system will improve when the ventilation shutdown is complete.

In our 2005 paper, we found that it is of the utmost importance that the deluge system is released quickly and that it operates as intended. Reliable data is available for nine cases where estimated time from ignition of fire to release of deluge could be identified, as could the extent of damages.

Vessel	Time to release	Damages, other findings
RoPax vessels		
Victoria Seaways	3 minutes	Limited damages
2009.R1	"immediately"	Damages to some lorries
2015.R1	8 minutes	Limited to one car
Mecklenburg-Vorpommern	8 minutes	One trailer damaged as well as some steel structures above this one. Deluge valve hard to operate (release delayed 3 to 5 minutes as a result)
Commodore	25 minutes	Several lorries and some structures damaged
Pearl of Scandinavia	35 minutes	Incorrect section released after 17 minutes, but corrected after 35 minutes. Car burnt out, and some damages to the adjacent trailer plus some structures (a few days off-hire)
Lisco Gloria	Did not operate	Total loss of vessel
Norman Atlantic	Did not operate	Total loss of vessel
Cargo Ro-Ro vessels		
UND Adriyatik	Did not operate	Total loss of vessel

There were three cases where deluge was not applied to the area on fire. All were open Ro-Ro spaces, and all three were total losses. The failures in the deluge systems include a combination of incorrect operation, the pump starter being in local mode and loss of main power.

The correlation between quick and, in particular, successful operation of the deluge system and limited damages to cargo and vessel is clear. The only fire not following the trend was on the Pearl of Scandinavia (correct area drenched after 35 minutes, still limited damages). The fire growth rate is unique for each Ro-Ro space fire, and the arrangement of adjacent vehicles in this fire appears to be favourable. The car was also parked near a transverse flooding bulkhead, which prevented the spread of fire in that direction.

It should be noted that the deluge was released well within 10 minutes in four cases. This proves that a quick response is possible when a water-based fixed fire-extinguishing system is provided. Compared with the water mist systems provided for the engine room, which typically discharge freshwater and have several remote release controls, we have recorded response time as quick as 0.5 to 2.0 minutes. By using some of the lessons learned from the work done on engine-room safety, the response time for Ro-Ro spaces can be further reduced. A CCTV system was provided, and was found to be a useful support tool in several of the fire cases.

3.4 Performance of CO_2 systems

General Ro-Ro vessels and vehicle carriers are typically protected with a low-pressure or high-pressure CO_2 system. This gas is lethal in the concentrations needed to extinguish the fire, and it is of the utmost importance that all relevant safety checks are carried prior to the release of CO_2. Further, unlike deluge the CO_2 cannot be released before all ventilation dampers are closed. In a large Ro-Ro cargo hold, this can take some time for some designs. Depending on the size and arrangement of cargo holds, it may be difficult to release CO_2 quicker than within 10 to 15 minutes.

Vessel	Time to release	Damages, other findings
Cargo Ro-Ro vessels / Vehicle carriers		
Corona Seaways	15 minutes	Some cars/trucks damaged. Limited damage to structure
2012.V3	20 minutes	Damage to several vehicles, some damage to structure
Pyxis	22 minutes	Damage to many vehicles, damages to structure. Chief engineer did not return from his search, later found dead

There are reliable data for three cases. For two other cases (vehicle carriers), it can be confirmed that CO_2 was used, but the time to release is not available. In our 2005 report, we were able to identify several failures in fires where crew tried to release the low-pressure CO_2 system, whereas no such incidents were found in the fires recorded between 2005 and 2016.

Damages are less severe than could be anticipated based on the time to release of CO_2. Restricted supply of air for these closed Ro-Ro spaces could have contributed positively to the outcomes.

Combining all data would indicate that, for a closed cargo hold, you need to activate the fixed fire-extinguishing system (well) within 10 minutes in order to limit damages. If the fixed system or fire teams are applied after 20 minutes, there will be major damages, and the safety of the vessel may be at risk. This window of opportunity will typically be even shorter for an open Ro-Ro space design.

3.5 Performance of fire-detection systems and fire-confirmation procedures

RoPax vessels shall have smoke detector systems for closed spaces. Fire detection is also required for open Ro-Ro spaces, but smoke detectors may be unreliable for parts of these, and a suitable combination of flame and heat detectors can be considered. Fire detection is not required for weather decks.

Cargo vessels follow the same concept, except that smoke-sampling systems may be used for closed cargo spaces. In most cases, no exact time for the start of the fire is stated. If the fire is small when detected, it is assumed that the time for detection is rather short, and the entry "quickly" has been used.

Vessel	Time to detect	Means of detection, other findings
RoPax vessels		
Victoria Seaways	Quickly	Detected by fire-detection system and quickly confirmed by CCTV
Pearl of Scandinavia	Quickly	Detected by fire-detection and quickly confirmed by safety patrol and CCTV, but origin of fire was mistaken (subsequently incorrect deluge section was released – this was corrected after 15 to 20 minutes)
Mecklenburg-Vorpommern	Quickly	Detected by crew, which happened to be passing through the area. Alarm from fire detection system 2 minutes later on
Lisco Gloria	Quickly	Detected by fire patrol and almost simultaneously by the crew due to the fire-detection system. Fire confirmed by patrol and CCTV
Commodore Clipper	Quickly	Detected by fire-detection system (after 4 to 5 minutes). Alarm assumed to be a problem with the detection system; fire was therefore confirmed after a delay of 10 to 15 minutes
Cargo Ro-Ro vessels		
Corona Seaways	Quickly	Detected by fire-detection system and quickly confirmed by CCTV
2013.C1	Immediately	Visual detection (and confirmation) from bridge, as they could see the events on the forward weather deck
UND Adriyatik	Not known	Smoke detection on main deck. Fire quickly confirmed by crew member when entering the space (by then a large fire)
Vehicle carriers		
2012.V3	Quickly	Detected by fire-detection system and confirmed by safety team
Pyxis	Assumed to be quickly	Detected by sampling extraction smoke-detection system and confirmed by crew when entering the space

Reliable data is available for 10 cases. The time to detect the fire is short for at least eight of these, and there are no indications that there were significant delays for the two remaining cases. The fire was detected by the fire detection system in seven cases, by fire patrol/crew in two cases, and essentially simultaneously by the fire-detection system and fire patrol in one case.

The time needed to confirm the fire and establish the location of the fire tells a slightly different story, as this is the part where precious time may be lost. Five cases were quickly confirmed by use of CCTV or crew entering the space, whereas one fire was immediately confirmed from the bridge (fire on weather deck). In two cases, there were delays (one where crew assumed a problem with the fire-detection system, and one where the location of the fire was initially mistaken, but later corrected).

CCTV was a useful tool in several of the fires, although smoke impaired visibility rather quickly in most cases. In some of the fires, the crew could observe that new detectors triggered the alarm, but this information was inaccurate. Combined smoke and heat detectors are assumed to be useful, as the heat detectors can pinpoint the extent of the fire (smoke is dispersed to areas not on fire; smoke detectors are therefore not reliable for the purpose of identifying the location of the fire).

4 NEW RULES APPLICABLE TO RO-RO SPACES

Several SOLAS amendments have been made recently which will enhance the safety of Ro-Ro vessels. The majority entered into force in or after 2010 , and none of the vessels identified with a fire casualty in this report were required to be in compliance with these. However, two requirements were retroactive, and it is assumed that these may have contributed positively in some of the accidents (in particular, the requirements addressing the protection of water drains).

The new requirements are:

Item	Regulation	Vessel type	Entered into force
Means to prevent blockage of drainage arrangement	SOLAS Ch. II-2 Reg.20.6.1.5	All Ro-Ro vessels fitted a deluge system	January 1st 2010 for new ships First survey after 2010 for existing ships
A30 structural fire protection between different Ro-Ro compartments	SOLAS Ch. II-2 Reg.9.2.3.3	Cargo vessels (incl. vehicle carriers) with Ro-Ro decks	July 1st 2014 for new ships
Enhanced application rates and design requirements for deluge systems	SOLAS Ch. II-2 Reg. 20.6.1	All Ro-Ro vessels fitted a deluge system	July 1st 2014 for new ships
Requirements for vehicle carriers carrying vehicles with alternative fuel	SOLAS Ch. II-2 Reg.20-1	Only vehicle carriers	January 1st 2016 for new ships
	IMO MSC.1/Circ. 1471		Existing ships should apply IMO MSC.1/Circ. 1471

It is presumed that the rules for deluge and draining will enhance the reliability and performance of new deluge systems and reduce the likelihood of firefighting being interrupted by stability problems. We did identify a few cases with stability problems in our previous 2005 paper, and the al-Salam Boccaccio 98 capsized with disastrous results in 2005 due to water on deck within the Ro-Ro spaces. In this paper, we have only noted some problems for one incident due to a large amount of debris (2010, Commodore) and recorded the Victoria Seaways (2013) as a success in this respect.

The new A30 requirement may reduce the risk for a total loss (where fire cannot be contained to a single cargo hold), and it may also reduce the risk of cargo in other holds being scrapped after a fire.

5 NEW CARGOES

The demand for alternative-fuel vehicles (AFV) is increasing, and many carmakers offer new models in these segments. The following categorization can be made:

1. Electric vehicles
2. Natural-gas vehicles (including LNG/LPG)
3. Hydrogen-fuelled vehicles
4. Ethanol vehicles
5. Hybrid vehicles

Vehicle carriers carrying electric vehicles shall comply with SP 961 and 962 in the IMO Code for Dangerous Goods which implies that cargo hold with electric vehicles provided with lithium ion batteries shall comply with the requirement applicable for class 9 dangerous goods.

For vehicles fuelled with compressed hydrogen or natural gas the regulations mentioned in Ch.4 are now available (SOLAS Ch. II-2 Reg.20-1 and IMO MSC.1/Circ. 1471). For new vessels all electrical equipment shall be EX, ventilation shall be operated and portable gas detectors shall be provided. Existing vessel shall also have portable gas detectors on board and they "should comply with the other requirements (EX and ventilation) as appropriate / to the satisfaction of the Administration."

There are not yet reliable fire risk data for electric vehicles and the issue of charging electric cars (in particular supercharging at 100 kW or more per unit) has by some been identified as a hazard and that these vehicles should be regarded as a hazardous item. This risk associated with charging is not assessed by this paper as ship operators do typically not offer or allow charging of electric cars on board these vessels. It should also be noted that there are also hazards unique for the gasoline / diesel cars that may counterbalance this picture (fires starting in exhaust system, etc.). Recent data from Norwegian authorities would even suggest that there are fewer fires for electric vehicles. 3% of all cars in Norway are now electric and we begin to see some reliable data on this (DSB - Norway).

We have identified one fire where an AFV was involved (Pearl of Scandinavia, 2010). It is important to emphasise that the vehicle in question was a rebuilt electric car (layman installation) which was charged on board without permission by the crew.

Until reliable data are available we would recommend owners adopting a cautious policy for the AFVs carried on board (see our recommendations in Ch.6). Fighting fires in AFVs introduce new challenges which the crew should be aware and trained for. It should be noted that the origin of the fire may be another vehicle or other items carried within the Ro-Ro cargo spaces. Fires in battery packages are difficult to put out but they can be cooled by use of water. A fire in ethanol and bio-ethanol fuel will behave rather differently than a fire in diesel / gasoline as foam being intended for use on oil products may be ineffective when used on alcohols such as ethanol. Leakage from a hydrogen fuelled vehicle is not very likely but if ignited it will cause a fire with a high heat release rate, although the fire itself is expected to be short-lived.

6 CONCLUSIONS/ADVICE TO OWNERS

6.1 Reduction of fire risk

Owners and operators should have a clear policy on what cargo and operations they accept on board Ro-Ro spaces:

a. Cargo should be screened, and old and towed second hand vehicles in particular should carefully checked before being allowed on board.
b. A policy on reefer units needs to be available. If accepted on board, they should be placed in dedicated areas (weather decks when possible, and preferably an area covered by CCTV). Power transfer cables should be in good condition, replaced frequently and only handled by designated crew. Reefer units of dubious quality should be rejected. Stowage area should be checked frequently during voyage.
c. Shift of cargo represents a risk. At least for cargo Ro-Ro and vehicle carriers, improved cargo securing and weather routing should be considered.
d. It is recommended that access to all kind of Ro-Ro spaces (including open Ro-Ro spaces) be restricted during voyage.
e. Un-authorized charging of electric cars should be banned. Electric sockets should be marked and secured, and fire patrol on RoPax should be instructed to remove charging connections if found. This does not mean that a carefully designed charging arrangement could not be approved for a future design.
f. For hydrogen vehicles, good locations (along bulkheads, etc.) minimizing damages in case hydrogen is released and ignited should be considered when available.

6.2 Fighting fires

Quick release of the fixed fire-extinguishing system is important, in particular for open Ro-Ro decks where the window of opportunity may be less than 10 to 15 minutes:

a. Time should be assigned for the crew to familiarize themselves with the fixed fire-extinguishing system.
b. Realistic training on the use of the fixed fire extinguishing system should be implemented with company defined goals for release times (for instance, 3 minutes for deluge systems and 15 minutes for CO_2 systems). Drills should be performed frequently in a realistic manner, preferably simulating failure of key components (see DNV GL best practice on the subject).
c. It should be verified that labelling and instructions (within CO_2 room or deluge station, and at pumps, ventilation dampers, etc.) are up to date and correct.
d. A policy on how to handle alternative-fuel vehicles should be developed, if applicable (know-how on correct firefighting strategy/challenges), although this is not identified as a major risk (it is an unknown risk).

6.3 Post fire

Care should be taken when opening closed cargo holds (in particular, those flooded with CO_2, as this media provides limited cooling). Smoke divers with infrared cameras should verify that no notable heat remains before venting out the CO_2. The shore fire brigade should be on standby with capability to quickly move trucks and cars out of the Ro-Ro space. It is recommended that an emergency plan for alternative evacuation of passengers be available on board RoPax vessels, as these vessels may approach an alternative port or terminal in case of a fire. Exit platforms may be incompatible, and operation of alternative shell doors may be impaired by the fire.

6.4 New designs

a. The measures defined by DNV GL additional class notation F-AMC (Pt. 6 Ch. 5 Sec. 4) should be considered for new buildings. These measures includes enhanced reliability of the fixed fire-extinguishing system, improved fire detection and CCTV systems, better specified portable equipment, additional firefighter's outfit and better UHF/VHF coverage.
b. If an open Ro-Ro space design is implemented for a newbuilding, it is important to consider the impact on all relevant safety systems (location of lifeboats and other LSA equipment, location of air intakes for main and emergency power, etc.).
c. Power circuits serving reefer units shall be equipped with ground fault detection providing alarm to a manned control station.

Annex 1 – Fires RoPax vessels, 2005–2015 (18 fires on Ro-Ro deck)

RoPax, 2005–2015 (18 fires on Ro-Ro deck)

Date	Ship	Built	Grt	Cause	Comments
2015 October	2015.R1	2001	44,437	Car (charging caravan?)	Quick reaction, close to igniting caravan
2015 August	Sunflower Daisetsu	2001	11,401	Reefer trailer?	1 fatality/domestic?
2015 April	Sorrento	2003	25,984	(-)	4 crew injured
2014 December	Norman Atlantic	2009	26,904	(reefer unit?)	9 fatalities, 19 missing
2014 April	2014.R1	2006	12,895	Started in truck	
2013 June	2013.R2	2000	33,724	(-)	(minor fire)
2013 April	Victoria Seaways	2009	25,675	Electrical fault in a second-hand car	
2013 January	2013.R1	1986	19,504	Trailer on car deck	
2012 November	2012.R1	1979	27,239	(-)	
2010 November	Pearl of Scandinavia	1989	40,231	Un-authorized charging of electric car	
2010 November	Mecklenburg-Vorpommern	1996	37,987	Battery of minibus	
2010 October	Lisco Gloria	2002	20,140	Presumably power supply to reefer unit	Total loss
2010 June	Commodore	1999	14,000	Power supply to reefer unit	Major damages
2009 May	2009.R2	1999	31,041	(-)	
2009 January	2009.R1	2003	35,736	(Undeclared) items inside truck	Extinguished by deluge
2008 April	2008.R1	1980	12,175	Originated presumably in lorry	
2007 August	2007.R1	2001	36,468	Truck loaded with aluminium powder	
2005 May	2005.R1	1988	34,384	Started in car	(minor fire)

Notes.
Vessel name: Some entries are not published in this paper, but identified as 20xx.Ry (xx = year of incident), (Ry = fire on a RoPax, fire no. y that year).

Annex 2 – Cargo Ro-Ro ships (not vehicle carriers), 2005–2015 (8 fires on Ro-Ro deck)
Cargo Ro-Ro ships, including ConRo (not vehicle carriers), 2005–2015 (8 fires on Ro-Ro deck)

Date	Ship	Built	Grt	Cause	Comments
2015 March	2015.C2	1980	4,688	(-)	
2015 February	2015.C1	1991	7,578	Started in items (cars?) stored on a closed Ro-Ro deck	
2014 April	Repubblica Di Roma	1992	42,001	(-)	Did not return to service
2013 December	Corona Seaways	2008	25,609	Electrical defect in one of the vehicles' engine starting systems	Some cars/trucks damaged. Limited damage to tructure. CO_2 used after 15 minutes
2013 November	2013.C1	2000	24,196	Shifting of cargo on open deck	On fire for hours (weather deck fire). Some structural damage
2013 May	Atlantic Cartier (ConRo)	1985	58,358	(-)	
2008 February	UND Adriyatik	2001	26,469	(-)	Total loss. Deluge did not operate. Loss of power
2005 January	2005.C1	2000	21,005	Shifting of cargo on weather deck	On fire for several hours (weather deck fire). Some structural damage

Notes.
Vessel name: Some entries are not published in this paper, but identified as 20xx.Cy (xx = year of incident), (Cy = fire on a general cargo Ro-Ro, fire no. y that year – excluding fires identified by name).

Annex 3 – Ro-ro/vehicle carriers, 2005–2015 (9 fires on Ro-Ro deck)
Vehicle carriers, 2005–2015 (9 fires on Ro-Ro deck)

Date	Vessel name	Built	Grt	Cause	Comments
2015 June	2015.V1	1991	52,288	ABS brakes/electric system in a used car	
2014 April	Asian Empire	1998	71,383	(-)	Crew abandoned vessel
2013 October	2013.V1	2007	38,651	(-)	
2012 December	2012.V3	2010	60,396	(-)	
2012 August	2012.V2	2007	55,775	(-)	
2012 March	2012.V3	2007	57,280	Shifting of cargo	CO_2 released after 20 minutes Reignited in a minor fire 2 days later when cargo hold was opened
2009 January	2009.V1	1981	45,365	(-)	Scrapped
2008 October	Pyxis	1986	43,425	(New) car, electric system?	1 fatality (CO_2)
2007 July	2008.V2	2006	41,662	(-)	On fire for 6 hours/Extinguished by foam

Notes.
Vessel name: Some entries are not published in this paper, but identified as 20xx.Py (xx = year of incident), (Vy = fire on a vehicle carrier, fire no. y that year – excluding fires identified by name)

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