MINISTRY OF INFRASTRUCTURE AND TRASPORT

Directorate General for Rail and Marine Investigations

3^ Division – Marine Investigations

Fire on Board Ro-Ro Pax *SORRENTO*

28 April 2015

Final Report

The aim of the present investigation, which was carried out in accordance with the above mentioned Decree, is that of preventing any possible future accident of this kind, by ascertaining and analysing the related causes and circumstances.

The inquiries, performed pursuant to the discipline established by the mentioned Decree, are not design to determine any kind of liability.

The inquiries reports, even in relation to the findings included and the conclusions drawn, cannot be considered as a source of evidence in any administrative or penal proceeding.

Disclaimer:

Some contents of chapter 4 “analyses” were extracted from the Norman Atlantic Investigation report and from the investigation carried by the Spanish Guardia Civil on the Sorrento case.

Issued by:

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GLOSSARY

AIS: Automatic Identification System. Automatic system - prescribed by Regulation 19 of Chapter V of SOLAS - automatically sending and receiving travel data, the IMO identification number for each ship and other relevant information;

A.M.: Maritime Authority (Harbour office or Consulate);

ACCIONA TRANSMEDITERRANEA: TRANSEMDITERRANEA Calle Anabel Segura 11, Compleho Albertos, Edificio D Planta 2° - Alcobentas MADRID

CD: Compact Disk;

COG: Course Over Ground;

COMPANY: Reference is made to the managing company VISEMAR DI NAVIGAZIONE;

STCW 78/95 CONVENTION: Standards of Training, Certification and Watchkeeping;

C/P: Charter Party;

DAU: Data Acquisition Unit;

D.O.C.: *Document Of Compliance,* namely the Certificate issued by the Managing Company, pursuant to the ISM Code and made compulsory by Chapter IX of the SOLAS convention;

DMM: Data Management Module;

DPR 435/91: the Regulation for navigation safety and the safeguard of human life at sea issued through the Presidential Decree dated 8 November 1991, n. 435;

DPU: Data Processing Unit;

ECDIS: Electronic Chart Display and Information System;

FRM: Final Recording Medium. It is the information stored in the so called “black box”, namely in the armoured box which can be recovered even in case of accident;

GMDSS: Global Maritime Distress and Safety System;

GMT: Greenwich Mean Time. It basically corresponds to UTC;

HDG: Heading;

IMO: International Maritime Organisation;

IP: Internet Protocol;

ISM: International Safety Management;

SMS MANUAL: Safety Management System Manual;

MB: Mega Byte;

MES: Marine Evacuation System

MHZ: Mega Hertz;

M/V: Motor vessel;

NM: Nautical Miles;

NMEA: National Marine Electronics Association. Data communication standard used, in particular, in navigation and in the communication of GPS satellite data;

PC: Personal Computer;

PSC: Port State Control;

R.O.: Recognized Organization;

RSM: Remote Storage Module;

SMC: Safety Management Certificate;

SMS: Safety Management System;

SOG: Speed Over Ground;

SOLAS: Safety Of Life And Sea. International Convention for the Safeguard of Human Life at sea adopted on 1 November 1974, as amended, ratified by Italy through Law 313/80;

SSO: Ship Security Officer;

SPD: Speed;

TLC: Telecommunication;

UTC: Universal Coordinate Time. Reference time zone used to calculate all the other time zones in the world. It is derived from the GMT, to which it corresponds, with the exception of infinitesimal approximations, that's why it is sometimes still called GMT;

VDR: Voyage Data Recorder. HW and SW system recording travel data, prescribed by Regulation 20 of Chapter V of SOLAS;

VGA: Video Graphics Array;

VHF: Very High Frequency;

VRM: Variable Range Marker.

1. SUMMARY

On 28.04.2015, at 11:45 (UTC), about 20 miles off West of Palma de Mallorca island (Spain), occurred a very serious fire on board the Ro-Ro-Pax SORRENTO, Italian flag - IMO 9264312, registered at nr. 120 I.R. of Palermo, owner Atlantica di Navigazione Spa, part of the Grimaldi Group and chartered to Transmediterranea Acciona , employed on the route Valencia- Palma de Mallorca.

As a consequence of the casualty, the ship was lost. No injuries and no fatalities were registered.

2. FACTUAL INFORMATION

2.1 Photo of SORRENTO

2.2 Ship Particulars

Name:	SORRENTO
Flag:	ITALY
IMO Number:	9264312
Registry no.:	No. 120 I.R. of Palermo
Type of ship:	Passengers and RO-RO CARGO
Call sign:	IBDD
Shipowner:	*ATLANTICA DI NAVIGAZIONE S.p.a – GRUPPO GRIMALDI*
Charterer (Deck & Engine):	TRASMEDITERRANEA
Builder/Year	2003 – *Cantiere Navale Visentini Srl*
Keel laid:	2003
Length, o.a..:	186.35 mt
Width:	25.60 mt
Height:	9.15 mt
Draught:	6.79 mt
GT/Net tonnage:	25984 GT / 8362 NT
Length BPP.:	169,50 mt
Hull material:	Steel
Number of passengers:	954
Type of propulsion:	propeller
Main engines:	2
EGs:	Diesel Electric CATERPILLAR
Propellers:	2 variable pitch
Thrusters:	(aft 3 x 1720 KW - bow 3 x 1720 KW)
Max speed:	23.5 kts

2.3 Voyage Particulars

Port of departure: Palma de Mallorca

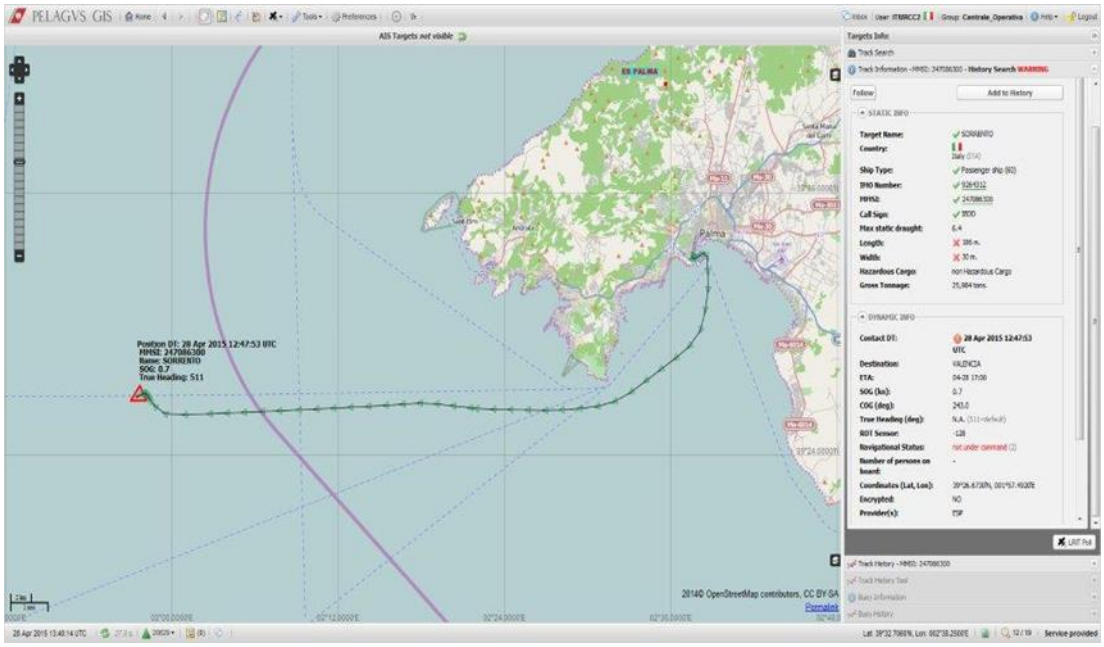
Port of arrival: Valencia

Type of voyage: Ro-Ro – pax domestic line

Number of passengers: 106

Other people on board: 4

Crew list: 46



2.4 Information on Casualty

Type of event: Very serious casualty (Fire on board)

Date and time: 28/04/2015 - 11:45 (UTC)[1]

Location or area of the casualty: Open Sea – 20 Nm off Palma de Mallorca

Position: Lat. 39 ° 25.93' N - LONG. 002 ° 03.956' E

Sea Weather Conditions: Very rough sea

Wind, Moderate 4

Moderate Visibility

Phase of the voyage: sailing

And part of the voyage: from Palma de Mallorca to Valencia

Affected part of the ship: Open RO/RO cargo spaces – Deck 4 Frame 157

Consequences:

- Dead or missing people: //
- Injured: 14.
- Survivors: 156
- Loss of the unit

2.5 Shore Authority Involvement and Emergency Response

2.5.1 Authorities Involved

Comando / Ente
MRSC PALMA

[1] Time taken from the first detected alarm based on VDR data

2.5.2 Actions Undertaken

Immediate coordination of the SAR activities by MRSC PALMA. On the SAR scene were employed following units:

SAR Units employed

Name	TYPE	ORGANIZATION	COUNTRY
	PATROL BOAT	COAST GUARD	SPAIN
	HELICOPTER	COAST GUARD	SPAIN

Merchants vessels intervened or diverted for assistance

NOME	nr. IMO	TIPO ASSETTO	STATO DI BANDIERA
PUGLIA	9031703	RO/ro PAX	ITALY
VISEMAR ONE	9498743	Ro/ro PAX	ITALY
MARTAMAR		TUG	ITALY
GIANEMILIO C		TUG	ITALY
CLARA COMPOAMOR		TUG	SPAIN
SEMAC		TUG	SPAIN

2.5.3 Results Obtained

During the rescue operations all the 156 people, that were on board the ship, were safely rescued thanks to the coordination of the activities operated by MRSC PALMA together with the ships intervened for assistance.

Just 14 people suffered very light injuries as a consequence of smoke intoxication.

The towed unit arrived in the port of Sagunto (SPAIN) on 5 May, 2015.

3. NARRATIVE

On 28.04.2015, at 11:45 (UTC), about 20 miles off West of Palma de Mallorca island (Spain), occurred a very serious fire on board the Ro-Ro-Pax SORRENTO, Italian flag - IMO 9264312, registered at nr. 120 I.R. of Palermo, owner Atlantica di Navigazione Spa, part of the Grimaldi Group and chartered to Transmediterranea, employed on the route Valencia- Palma de Mallorca. The ship had left the port of Palma de Mallorca at 9:55 (UTC), with 156 people on board (46 crew, 3 animators, 1 company Trasmediterranea employee and 106 passengers including 1 infant), and 123 trucks.

The crew was of Italian nationality (14 of which 9 officers and 3 petty officers, enrolled by the chartered company Grimaldi Euromed S.p.a.); Filipina (8 including 1 petty officer and 7 sailors, always enrolled by the aforementioned company Grimaldi euromed S.p.a.); Spanish (10 of the hotel dpt, including the purser, enrolled in the Trasmediterranea); onduregna (14 of the hotel dpt, enrolled by the company Ibernor-Schembri).

The management company was Grimaldi Deep Sea S.p.a. - Imo n. 1468950.

For reasons ascertained within this report, while the ferry proceeded with a 270 ° course at 19 knots of speed, a fire developed at the garage deck n. 4 (smoke detector placed on the frame 168, forward center - lanes 4-5 of 8, second row of trucks starting from the bow, where had been boarded two refrigerated trucks) that, despite the intervention of the firefighting teams (firefighting team - albeit, it would seem, not complete - and cooling) and the activation of the Drencher fixed firefighting system, proved to be rapidly uncontrollable (the strong wind that almost hit the ship transversely, considering that it was an open bridge , fueled the combustion), also occurred a short time after a total irreversible blackout (probably due to the fact that most of the electrical wiring of the on-board systems are wired under the top of the deck4), forcing the Command to board to activate the ship abandonment procedures, given that it is impossible to combat the fire effectively.

For this reason, after having launched a distress signal at 12:12 (UTC), the Captain ordered abandon ship. the Italian ferries PUGLIA, IMO 9031703, and VISEMAR ONE, IMO 9498743, in transit in the area, provided immediate assistance and shortly after a helicopter and a patrol boat of the Spanish Coast Guard (ACRUX) together with the tug MARTAMAR.

At about 12.35 am, despite the adverse weather conditions (wind force 4 from NW, west sea 4), the starboard lifeboat (windward) was lowered with 113 people (103 passengers, 1 child <1 year, 3 animators, 1 guest; crew members), heading to M/V Puglia where they transshipped transiting from the left side pilot boarding (the engine of the lance went off just when it almost reached the edge of Puglia, so as to make it necessary to use ropes to recover the lifeboat to the pilot boarding).

Shortly thereafter, the left-hand lifeboat was also put into the water with 33 people (31 crew members and 2 passengers) including the Captain (pushed by the bosun who in turn had been invited to climb first by the Captain). However, after about 500 meters the engine was turned off (someone claims due to the presence of an extraneous body in the propeller, another version instead for a battery problem) and so the lifeboat was towed by a rescue boat of the Visemar One meanwhile put in sea. Coming under the bow of the Visemar One, following the failed attempt to tranship on the same ship, the attention of the rescue patrol boat Acrux was recalled, after having caused the castaways to

climb, and subsequently completed the transhipment on Puglia (except for the Commander and 1st attendant who were held on board the Acrux for another two hours).

Afterwards, the crew of the lifeboat launched by the sea from Puglia rescued 3 crew members that launched themselves in the water from the bow, where they were blocked, due to smoke and flames, with 3 other crew members, rescued a few moments after the helicopter of the "guard civil" (all six members of the crew of Italian nationality who had tried to fight the fire until it was possible).

Subsequently, the aforementioned lifeboat has also recovered the last 4 crew members, also of Italian nationality, remained on board, descended into the water from the boarding point of the starboard lifeboat (last to abandon the ship was the bosun).

In conclusion, except for the 3 crew members rescued with the helicopter from the bow, all the remaining 153 castaways (including the child) were transhipped on the Puglia ship and were subsequently transported to the port of Palma de Mallorca (except a Filipino seafarer in a state of shock, recovered by the same ship from Puglia with a helicopter of the "Guardia civil"), where the landing operations were completed at 18:00.

No people was seriously injured (14 people were hospitalized for light bruises and / or intoxication symptoms from smoke inhalation and quickly left the hospital), no pollution was reported as well. The fire was extinguished only in the following days and it was proceeded with the hull cooling, also opening of the passages between the bridge 4 and the bridge 3 in order to allow ventilation of the latter.

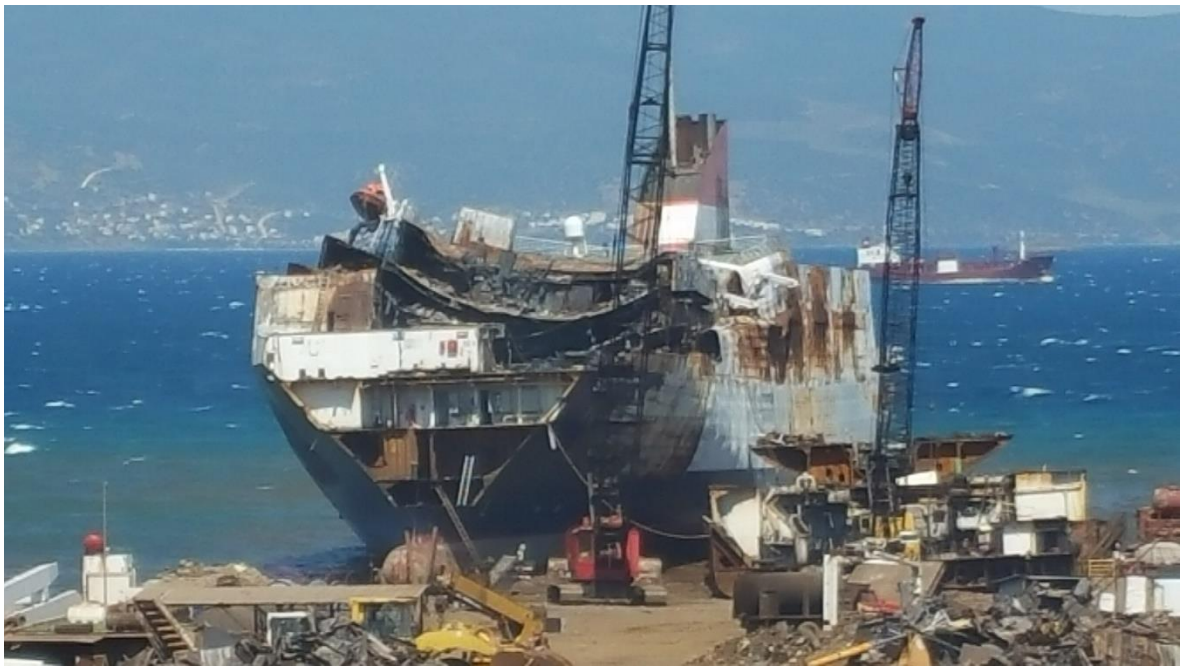
After the ship was in safety conditions and under control, it was decided the towing of the wreck carried out by the tug Gianemilio C, together with the tugs CLARA COMPOAMOR and SEMAC and other various smaller units for aid and logistical support. The M/V SORRENTO finally moored on 05/05/2015 in the port of Sagunto (near Valencia).

3.1 Investigation Activity

The ship was finally bought by Norwegian Hull Club, changed name into “RENTO” and transferred to Aliaga for the demolition.

DIGIFEMA Investigation team went on board the ship as she arrived in Turkey in order to get eventual further evidences that couldn’t be gathered before because of the dangerous conditions. IN particular it was possible to take the automation data pc and get the hard drive. Unfortunately, the automation system installed on board Sorrento didn’t record any information on it and it was containing only the operating system.

The ship was finally demolished by the end of May 2016.



Pic 1: M/V SORRENTO – Initial phases of demolition (21 apr 2016)

4. ANALYSIS

4.1 Ship organization

In this chapter, the shipboard arrangement and organization is analysed, with reference to the related regulatory framework and the internal procedures established by the SMS. The context, the measures actually taken by the personnel on board and the kind of emergency will also be considered. The following table summarizes the activities which will be described in the following paragraphs.

Chronology	Activity	Ref. Reg.	Requirement	ISM Procedure
Shipboard organization	Crew List Minimum Safe Manning	SOLAS (em 99-00) CV/R.14 DPR 435 Art.201 C.N. Art 317 R.C.N. Art 426	The presence of a minimum number of persons on board is required so as to ensure the safety of those at sea.	2.1.1 SMS – Staff recruiting and selection
Shipboard organization	Certificates of the personnel on board. Familiarisation with safety procedures when boarding. Familiarisation with on board activities.	STCW R.I-14/A-I 14 A-V/3/A-VI/1-2 ISM 6 SOLAS (am 99-00) C II-2/R.15 SOLAS (am 2006) C III/R.19	The Company shall ensure that the personnel aboard is duly certified, pursuant to STCW and to the national regulations. The Company shall also ensure that the personnel gets familiar with the tasks assigned on board and in case of emergency.	2.1.6 1 SMS "Certificates of the personnel aboard" 2.1.8 Familiarisation with safety measures when boarding SMS – 2.1.9 SMS Familiarisation with tasks to be performed on board
Shipboard organization	Working language	SOLAS (am. 99-00) C.V – R.14 ISM.6	The Company shall choose a working language on board, so as to ensure effective safety performances and shall provide proper information	2.9 SMS working and command language

Shipboard organization	Muster list task	SOLAS (am 96-98) C.III – R.8 and 37 DPR 435 – ART 203 SOLAS C III R 19 e 20 – artt. 232, 233 and DPR 435/	The personnel in charge of the muster list shall be certified and be familiar with: - Basic Safety Training; - have a proficiency level in survival craft and rescue boats" (MAMS) - MABEV - crew management	SMS -Crew training SMS – Preparation of the Muster List
Shipboard organization	pre-departure/arrival activities – ship in port safety of the loading operations and bunkering – passenger registration system	SOLAS C. II-I R. 20,21,22,23 – C. III, R. 20 C. V R. 26 – artt 225,226,229 and 230 DPR 435/91 SOLAS C. II-I regulation 20, 21, 22, 23 e C. III R. 20 – C. V R. 26		12.2.10 SMS. Safety and protection of the vehicle storage deck 12.2.11 "regulation of the ventilation of the vehicle storage decks" 12.2.13 SMS – "Fire patrol of the vehicle cargo decks" 12.2.15 SMS – "Access control of the vehicle cargo decks during navigation"

Shipboard organization	Operations on ro-ro ships	Art. 297 Nav. Cod.– Cargo0 Securing Manual Circ. Series IV n. 7 of 13.3.1995 - Mimerc – Ris. IMO A 581(14) M.D. 13/10/1999 (Directive 98/41/EC)		16.4.1 SMS “Cargo lashing” 16.7 SMS . “safety precautions on the deck designed for the storage of vehicles – crew” 16.8 SMS. “safety precautions on the deck designed for the storage of vehicles – passengers” 16.10 SMS “Operations with mobile ramps, lifts and platforms”. 16.11 SMS “Ventilation of vehicle cargo decks” 16.12 SMS. Fire protection system on vehicle cargo decks 16.15 SMS. “Vehicles for the transport of refrigerated goods” 24.2 SMS : “Passengers registration”

4.1.2 Minimum Safe manning - Crew organization

Pursuant to the provisions established by the reference legislation (SOLAS 74 C V R 14. Art. 317 of the Nav. Code Art. 426 of Reg. C.N., art. 201 of DPR 435/91 as well as L. 27.02.199/8, n. 30 and followings), the ship shall be manned in compliance with the Minimum Safe manning, as established by the Flag State Administration, based on the regulation mentioned in the previous table.

In addition, on October 20, 2010, Italy issued Circular Letter n. 001, titled “Guidelines for drafting the MSM for Italian ships and fishing vessels, in compliance with resolution IMO A. 890 (21) as amended by Resolution IMO A. 955 (23)”. Such circular letter provides instructions concerning the draft of minimum manning tables for both new and existing ships.

The M/V “SORRENTO” has the provisional minimum safe manning table n. 35, issued on 8.7.2005 (day/month/year) by the Palermo Coast Guard office (Annex 1), which, for this specific case for the following composition:

Officers, nr. 9

Deck staff, nr. 6

Engine staff, nr. 4

Cabin staff, nr. 4

Complementary services, nr. 7

The ship *crew list* includes instead 48 boarded crew members at the time of the accident (Annex --- 2).

A total number of 28 members were provided by the ship owner for the “*deck & engine*” part, while the remaining ones, recruited mainly for cabin services were provided by the Charterer, as established by the charter party contract.

The staff nationality was mainly Italian and Spanish.

4.1.3 Working language on board

The working language on board shall be chosen by the Company, according to the provisions of Solas (em.99/00) – Chapter V – Regulation 14, and ISM code, paragraph 6.6.

Each crew member shall be able to understand the working language and, for some activities, to give orders and instructions, and consequently answer in the working language.

The working language shall enable a level of communication such that:

1) The crew performance level, with reference to safety activities, is adequate;
2) The information needed for implementing the SMS procedures are received;

The Company, with reference to the "SAFETY MANAGEMENT SYSTEM (SMS 5.3.1 – Annex 3-b), established, at page 5, that the working language on its ships shall be English.

Crewmembers embarked on board M/V SORRENTO that were interviewed were found to have a proper knowledge of the English language both Grimaldi and Transmediterranea personnel.

4.1.5 Safety certificates and operational restrictions

The ship left the port of Palma de Mallorca, with all the ship certificates being valid.

The analysis of the ship documents (statutory certificates) didn't reveal any shortcomings or irregularities (annex 4).

4.1.6 Loading and lashing operations

Chapter 12 of the SMS manual, from paragraph 12.2.2.1 to 12.2.4.6, establishes the rules and precautions to be followed for loading, stowing and lashing vehicles on board.

In particular, paragraph 12.4.2.2 "Pre-shipment Operations" establishes that:

1. The Chief Mate finds the crew members available, who get assigned the tasks regarding the operations to be carried out, that will be established and assigned according to the operational needs;

2. The Chief Mate, in the presence of the crew who have received the tasks, holds a meeting with the terminal manager; the aim of this meeting is to establish the necessary coordination

of the operations to be carried out by the shore and shipboard personnel, so as to avoid any dangerous interference;

3. Moreover, there will be an exchange of information about the risks present both on board and on the dock;

4. In case it's necessary to use cargo-handling vehicles (tug masters, fork lifts, etc.), during the meeting it will be established how to use such vehicles, both if they are part of the ship's equipment or if they are the terminal's vehicles.

5. It's also necessary to agree upon the way in which to position signalmen who are responsible for giving on board assistance to drivers of vehicles (cars, trailers, heavy duty vehicles, cargo-handling vehicles in general). Signalmen almost always belong to the port workforce, except in cases of self-production, when a signalman is chosen between the crewmembers. In any case, **the Chief Mate** has to make sure that in all vehicle-handling operations, should the presence of signalmen be needed, they are made available in the most appropriate positions.

6. At the end of the meeting the officials (Chief Mate and Terminal Manager) sign a single document of coordination and risk evaluation (checklist) and a document that lists the tasks that have been assigned, signed by the people who have received the tasks, including the signalmen.

From the interviews collected, no problems were found in connection to the implementation and application of such procedures.

Situation of the cargo at the time of the accident

Cargo loaded in Palma de Mallorca:

- n. 239 commercial vehicles (trucks, minivan ecc);
- n. 2 passenger cars;

the ship departed from Palma with 108 passengers on board, destination Valencia.

Situation of deck 4

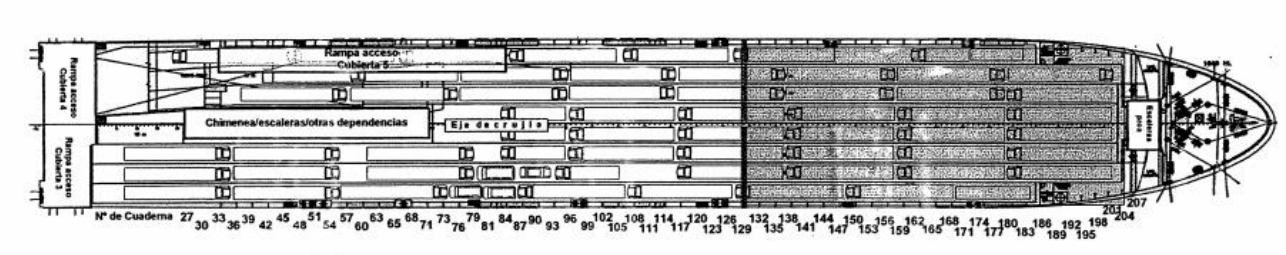


FIGURE 1 POSSIBLE CARGO SITUATION ON DECK 4

4.1.7 Further procedures concerning the loading operations

4.1.8 Watchkeeping on the navigation bridge

Watchkeeping on the navigation bridge is regulated by procedure under Chap. 4.6 SMS. At the time of the accident, the second watchkeeping team was on the navigation bridge (04.00 -08.00) and was made up of the following crew members:

- Seaman (Ship's wheel)
- 3nd mate

Such composition was compliant with the above mentioned procedure.

4.1.9 Working hours on board

The working hours on board are regulated by the specific regulation (MLC 2006, from Leg. Dec. 271/1999 art. 11, as amended and by the Convention STCW (A-VIII/1 – as amended by the Manila Conference).

All the staff members in charge of watchkeeping or safety related tasks, tasks concerning marine environment protection and security shall have the following average rest periods:

- At least 10 hours out of a period of 24;
- At least 77 hours out of a period of 7 days.

The working hours on board may be divided into two main time slots, one of which shall be of at least 6 consecutive hours; the time lapse between the two slots cannot be over 14 hours .

On board of the M/V SORRENTO, such aspects are regulated by procedure SMS 12.8.1.

Comunque la nave era partita da poche ore e l'equipaggio poteva ritenersi riposato.

4.2 Analysis of the emergency management and Muster list

Firstly it can be observed that the VDR of the M/N SORRENTO doesn't contain the same set of data of its twin ship Norman Atlantic, but a lower number; in particular, it's possible to collect the records of the voyage data, the bridge's audio records and some strings concerning the main alarms, but the situation of the fire doors is missing.

The provisions of the SOLAS Convention and of DPR 435/91 (art. 203) establish that a muster list shall be made for the ship, where all the tasks concerning the management of the different kind of emergencies are listed and assigned.

The muster list of the Sorrento consisted of 48 people (out of a total of 48 crew members). These people are in charge of different tasks, depending on the kind of emergency at issue, according to procedures n. 12.7.3.5 and followings of the SMS manual. The abandonment of the ship is instead regulated by procedure 12.7.13 of the abovementioned manual (such procedure, even if related to heavy weather conditions, can be kept valid also in case of abandonment in good weather conditions)

In particular the procedure 12.7.3.5 of the SMS Manual establishes as follows:

"*… if the alarm is activated during navigation, the officer on bridge watch keeping duty must call a member of the crew available to conduct the inspection; for such verification, the sailor on watch cannot be used as the lookout service must always be guaranteed.*

Actions to be carried out in any case of fire:

(i) immediately after the sound of the fire alarm

- Alert the "fire squad"

- Coordinate the announcements to the passengers with the Purser (roro pax ships)

- Turn on all the lights on the external decks, verifying if it's possible to do so on the fire site

- Give further information to the Engine Watch Officer (if the fire is outside of the engine room)

- Prepare all fire fighters equipment to be used

- If necessary, muster all crew

(ii) after the crew has been mustered

- Keep all the not directly involved personnel away from the affected area

- All involved personnel must wear the appropriate protective gear

- Inform the ***Designated Person Ashore***

- If the ship is in port, immediately inform the Port Authorities and the Fire Department and ask for the intervention of the closest representative of the Insurance

Prepared by:

The fire can affect the cargo area, the engine room, the kitchen area, the accommodations area or other areas of the ship. Pertaining to the site affected by the fire the following procedures must be followed.

FIRE IN THE CARGO AREA

In case of fire in the garage, it will have to be verified that all watertight doors and fire doors are closed, that ventilation is stopped, that dampers are closed, and that the power supply is shut off in the affected area. Depending on the nature of the fire, use one or all of the fire-fighting equipment mentioned below:

(i) Water through fire hydrants and hoses

(ii) Water sprays in the garages and on the decks (if installed – e.g. Drencher system)

(iii) CO2

(iii) Foam system (if installed)

(iv) Portable fire-fighting equipment (various fire extinguishers, foam backpacks, etc.)..."

Chronology of events:

Based on what has been derived from the VDR data and from the interviews, the following conclusions were drawn:

At around 11:45 UTC, the Second Mate alerts the Captain: "Captain, there's a fire in garage number 4!". He goes on the bridge and once there he soon realizes the gravity of the situation because there was a lot of black smoke coming from under the left wing of the bridge. Moreover, the fire-fighting system displayed that several fire detectors' alarms were active. The Deck Officer informs the Captain that the "assessment party" team has already been sent on the site. Soon the order is given to open all four Drenchers in the bow area. Moreover, the third mate receives the order to prepare and send the IMMARSAT message stating "fire on board". With the VHF, on channel 16, I contact the coastal station of Palma de Majorca, who asks us if we need help. In the meanwhile, the fire team (6 people), alerted together with the cooling team, was already in position with a rebreather and the other equipment provided. The cooling team was also in action. The electrician had electronically deactivated al garages from the engine room. The Chief Mate informs me via VHF that the fire is under control. At that point an announcement was made through the interphone to inform

the passengers that there was a fire in garage number 4 and that the fire squad was on site and that, at the moment, the fire was under control. I also informed the Palma de Majorca's radio station via VHF that the fire in that moment seemed to be under control and that I would have informed them of any further development."

4.2.1 The emergency phase

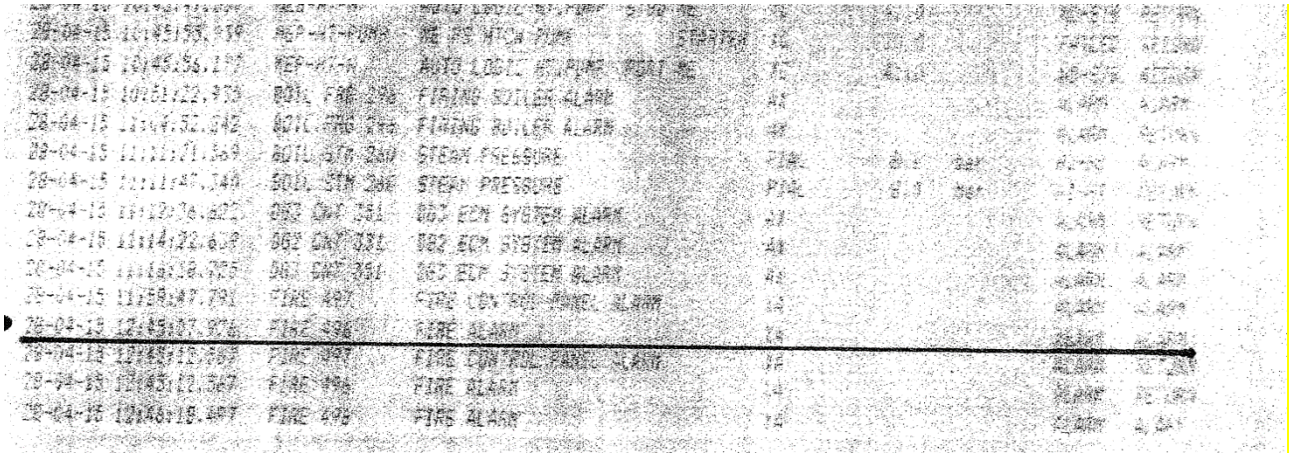


Fig. 2 ECR alarms printing

Dialogues with Timeline

11.45 the Captain is informed on the phone

11.48 the Captain is informed that the fire is on Deck 4, therefore the F team, consisting of 6 crew members coordinated by the Chief Mate, is sent to the F area

11.50 Order to open Drencher in sections 13-14-15

11.51 Alarm in Italian

11.52 Notice to passengers

11.53 Radio communication *"We have Fire On board*" with position and data on passengers and cargo

11.57 Radio communication that there is a fire on Deck 4 but that it's under control

12.07 The Chief Mate (Chief of the Foxtrot team) reports that they're having difficulties in keeping the fire under control, in particular for the presence of a lorry on fire in the middle of the ship that produces a lot of smoke and that the smoke is expanding more and more

12.15 The machine reports that there is a problem with the generators

12.26 Despite the efforts to stop the fire, the Captain commences preparations for evacuating the ship

12.37 The Captain reports that they are preparing to abandon ship when they cannot extinguish the fire

12.39 Ship abandoned

4.2.2 Internal examination of the wrecked ship and damage suffered

The inspection on board of the ship was possible only after some days, through the use of pumps for extracting air, because of the high levels of CO2 present on board, in particular in the lower decks; the pumps had been installed the same night the ship docked in the port of Sagunto.

It was possible to access the ship from three points: the stern ramp, the boarding stations placed on both sides of Deck 5 and through the practical doors placed in the central area of both sides of Deck 3.

Once the atmosphere inside the ship allowed for safe entrance, with the help of the ship plans given by the company and using one of the members of the “Svitzer” company’s rescue team as a guide, we carry out a general examination of the ship’s inside, entering from the stern hatch.

The main problems arise while carrying out the examination inside the ship and they are due to the state and placement of the cargo, the degree of damages to the ship caused by the heat, especially at the level of the first third of Deck 4 and of the deckhouse, where the structural weakening caused by the heat led to the deformation of the main structures both of the deck’s ceiling and the ceiling of the bow deckhouse. This situation makes it particularly difficult to move inside the ship, to determine the damage / the development of the fire from the analysis of the damaged materials, to identify the vehicles carried and to examine the different elements that make up the content of the wrecked ship.

On the other hand, the lack of a cargo plan makes it impossible to prove, identify and find large part of the vehicles that appear in the report on the cargo submitted by the rental company; the majority of them are heavy duty vehicles that are unloaded in a high percentage of cases (almost 80%), as it is usual on the journey Palma de Majorca-Valencia, and a quite high percentage of them are lorries consisting of a power head and a trailer coupled to it.

Even though no document shows the distribution of the vehicles on board, it was possible to verify that in the Decks number 1 and 2 and in the External decks there are only a few vehicles parked, while the Decks number 3 and 4 are practically full.

Photo 2: Right side view (01/05/2015)

Photo 3: Front view (01/05/2015)

Among the accesses to the decks there is the stern structure of the ship, inside of which there are the stern stairs that lead to the various decks of the hull, to the engine room, the control systems and the ship's other auxiliary rooms. This area has sustained damages due to the heat and smoke coming from inside the ship, since the damages are greater in the area of access to Deck 4, as it can be seen in the various images.

The inside of the stern structure shows in some areas a slight sign of damage caused by the smoke and heat coming from the outside, since the engines, the control and steering systems, some fuel tanks, generators and other similar mechanisms installed inside of it are apparently in good working order.

Close to the ECR there is also the Drencher room, from where – according to the interviews and the proof collected – the valves number 15, 16, 17 and 18, which had been opened to extinguish the fire and correspond to the forward area of Deck 4, were activated manually.

Photo 4: State of Drencher valves.

Entering Deck 4 from the stern ramp (back), it is possible to verify how the degree of the damage due to the heat showed by the walls and the roof, as well as the vehicles parked inside the garage, slowly increases as we move toward the bow area, by observing how in the front third of the garage deck (bow area) the higher sections of the frames show an intense deformation due to the heat, to the point that they reach the floor of the deck and even split in the centre. The deformation of the structures caused the collapse of the deck's ceiling in this front third of the garage, therefore crashing the vehicles parked in this area, whose structures had to be pretty weakened at the moment of collapse as a consequence of the fire.

Photo 5: View of the collapsed area

Photo 6: Inside Deck 4

Walking along the starboard side of Deck 4, it is possible to reach the front corridor of the car park where the intensity of the damage caused by the heat decreases. Afterwards it is possible to reach the area of the bow compartments, where the damages due to the heat decrease or are barely perceptible; this is due to the fact that the metal walls of the area largely protected it from the heat produced by the fire; in the middle of this area, there is a small corridor toward which the doors to

the car park and the bow of the ship are faced. At the end of this corridor, we can find the remains of some pipes damaged by the fire, which can be explained as part of the fire extinguishing system of the ship and that, as far as we know, had been used by the crew trying to tame the fire in its first stages.

The picture below represents the overall situation of Deck 4, which shows the approximate distribution of the parked vehicles, it lists the mountings of the ship's structure, it indicates the central axis of the hull or of the ship and which marks the windows in blue and the collapsed area in green.

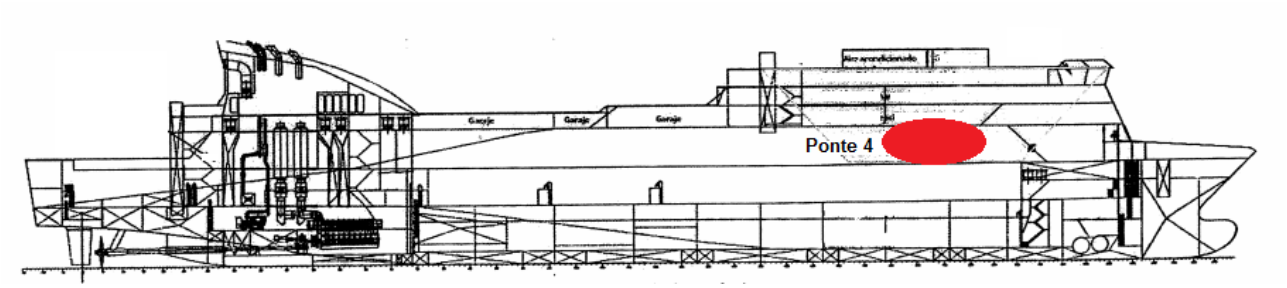


Figure 3: Right-side view indicating the area where the fire developed

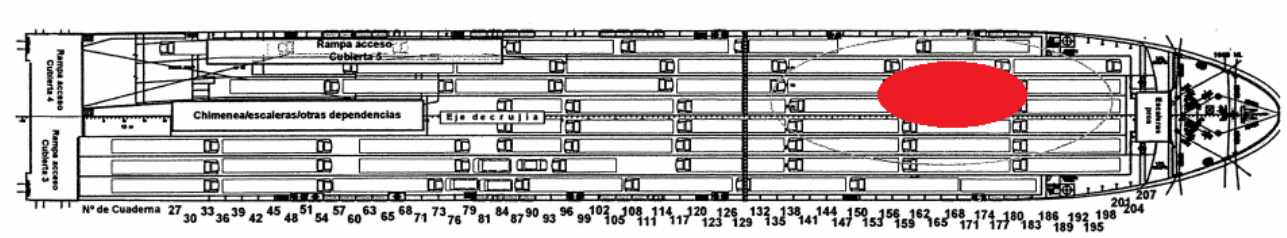


Figure 4: Deck 4 – Top view (the possible fire's point of origin is marked in red)

Deck 3 lacks openings on the hull, vehicles access it through the stern ramp.

It was mainly intended for parking vehicles and during the journey when the accident happened it was almost completely occupied by lorries, the majority of which was unloaded, and that have been intensely damaged by the fire, making their identification very difficult. The highest level of damage due to the heat in this deck is localised in its front medium section, where it can be seen how the heat pierced this deck's roof in some points and split some parts of the electrical wiring harness that runs over metal strips that are connected to the roof and along the deck. These damages are the result of the heat emanating from the higher deck.

4.2.3 Analysis of the human factor and influence over the emergency management

Although the Captain and the rest of the crew (the teams that intervened for containing/extinguishing the fire, in particular) had been significantly emotionally influenced by the situation, in this case the human factor hasn't had a negative impact on the overall management of the emergency and later of the evacuation.

Therefore it can be concluded that the emergency, although comparable to the one that occurred on board the Norman Atlantic, had a limited impact in this case, for the following factors:

- More favourable weather conditions
- The event occurring during daylight hours
- Rapid response of the crew and team work that can reasonably be ascribed to the effective training of both the crewmembers provided by the ship owner and those provided by the Renter (mainly room staff), together with a good knowledge of the English language and familiarity with the Spanish language that have facilitated communications – based on what has been found in interviews;
- A situation that was actually easier to manage, since the ship had sailed with only a third of the cargo/passengers compared to the ones boarded on the Norman, therefore the evacuation could be managed better by the crew.

However it is important to notice that despite the presence of more favourable elements, there are several analogies regarding some critical factors, especially like the rapidity of the blackout and the ineffectiveness of the fixed fire extinguishing systems, although they had been promptly activated in the right areas and had been supported/helped by the fire squad on site.

4.4 The situation of the rescue equipment

Contrary to what happened on the Norman Atlantic, in this case it was possible to use survival crafts (rafts/lifeboats) that allowed the safe evacuation of the ship.

4.5 Fire propagation analysis

For the analysis of the propagation of fire aboard the SORRENTO M / N is done partially referring to the studies conducted in the context of the investigation carried out for the fire of the M / N Norman Atlantic, since the ships presented many construction details and drawings in common.

The fire intensity, the high temperatures reached and the long time of action have made the identifications of fire causes and origin place very difficult, although, with the support of the objective data obtained from the VDR and of the inspections on the spot, the fire propagation and its possible origin could be reconstructed in a quite reliable way. For the purposes of the reconstruction, the evidence gathered on the spot was analysed and simulations were made with the support/guidance of the National Fire Service Department, based on mathematical models and specific software (FDS).

4.5.1 Origin of fire and analysis of the causes

It has to be said that the analysis of a fire dynamic is based on the research of evidence from places and/or objects, which, because of the high thermal stress and, sometimes, due to the many interventions made immediately after the event, have been subject to severe alterations;

To investigate the fire causes, an analytical method is needed. Such method is basically based on the knowledge of combustion mechanisms and uses a systematic and scientific approach when being applied, it uses the so called "*semiotics of fires*", namely a discipline which studies the marks left by fire.

Once the point of origin is established, its possible causes are analysed.

In this specific case, the fire was unfortunately particularly destructive, with high temperatures for a long time, as a consequence the marks left by the fire could not be easily analysed, so it was very difficult to identify its point of origin and cause.

So, as established by the NFPA 921 (National Fire Prevention Association) ed. 2001 in par. 18.17, in case the cause cannot be easily identified, the possible causes are analysed and the most likely is selected.

The causes which, even in the most diverse situations, lead to a fire breakout are always grouped in a series of well-known categories, which are listed here below:

a) abnormal functioning of gas-powered machineries,
b) cigarette butts,
c) use of flammable liquids,
d) use of open flames,
e) defect in n the electric system,
f) abnormal functioning of devices consuming electricity

So, also in the case analysed, the most reasonable method for identifying the origin of the fire, is to examine each of the above mentioned categories.

Having said that, in view of the alterations, which places were subject to, from the beginning of the fire and of its particularly destructive power, considered the temperatures generated, ***it was deemed appropriate to analyse the possible causes of the fire by progressive exclusion, until the identification of the most likely, if not certain, cause.***

a) ***Abnormal functioning of gas-powered machineries:*** no gas-powered machineries have been found in the garage, even though the possibility that a non-authorized passenger remained in the garage and used his own equipment for cooking and eating purposes cannot be excluded. So, such category of ***causes cannot be excluded***.
b) ***Cigarette butts:*** the real dangerousness, in terms of causing a fire, of a smoking discarded cigarette butt, was examined, with particular reference to what has been said in the Italian or foreign literature..

In the publication *"Investigazione sulle cause d'incendio"* (investigation on fire causes) published by the Centro Studi ed Esperienze del Corpo Nazionale dei Vigili del fuoco (Centre for Studies and Experiences of the national Fire-fighting Department) it is written that the temperature of incandescent tobacco "*is too low to cause the small portion of incandescent tobacco, in contact with wood or paper or cotton, do something more serious than a simple scorching, like causing the material to reach the ignition temperature".*

In addition to above, it is also stated: "A different evaluation is needed in case the cigarette butt ends up in an upholstered piece of furniture (for example between the armrests and backrests, sufficiently isolated, yet in the presence of a combustive agent): in such case (the cigarette) the isolation would prevent heat dispersion, so that temperature can reach up to 480° C. However, in such a case, the piece of furniture would need no less than an hour and a half to burn with open flames".

The conclusions above are accepted by technical authorities in all countries, although, in absence of other explanations, the cigarette butt is often empirically and easily identified as the origin of many fire events, while it is not always the case.

Anyway, considered that any cigarette butt falling on the floor wouldn't have found easily inflammable material, it is possible to state that ***the possibility that a cigarette could have triggered the fire can be excluded****.*

c) ***Use of flammable liquids:*** with reference to the presence of any inflammable liquids on the scenario, such liquids can be only the ones contained in truck cisterns and tanks. No other containers of inflammable liquids were found nor could they be manipulated. On deck 4, stern side, there is a room for small repairs, but the presence of inflammable liquids here is to be excluded. The observations above lead to state, with reasonable certainty, that in this specific case, if a malicious act (spilling inflammable liquid) is excluded, **the possibility that the presence of inflammable liquid caused the fire is to be ruled out.**

d) ***Use of open flames:*** there is no evidence that in the garage, particularly in that navigation phase, equipment or machineries requiring the use of open flames were used. So, this category of ***causes is to be excluded***.

e) ***Defect in n the electric system:*** through an electric system, regularly functioning, electrical currents flow. Such currents are defined by the number, power and features of loads. Such currents are defined operating currents and are the value which, when planning the system, is used to choose electrical cables equipment. In particular, electrical cables shall be able to permanently withstand the operating currents without enabling temperature to reach dangerous values for insulation materials.

When electricity runs through a conductor, due to the resistance encountered, heat is developed and that leads to a temperature increase in the conductor; such temperature is included in the normal range of values when the operating current doesn't exceed the conductor capacity in conditions of installation considered. So, it is always necessary to check that the operating current is either the same or lower than the conductor capacity.

The electrical breakdowns which may arise in a system, regardless of their cause, are always characterized by variations of the normal values of two fundamental electrical parameters, namely current and voltage. So, in theory, all possible cases of variations (of these two values) may occur, that is:

- **overcurrent** occurring in two particular breakdown situations: overload and short-circuit;

- **overvoltage** which can be transitional

- **undersupply** of current or voltage, which as extreme case, may lead to the out-of-service status.

In abnormal functioning situations, due to particular breakdown conditions, if protection devices aren't carefully designed, the system can potentially be a serious danger. The outbreak of fire, of electrical origin, is basically the consequence of the development of heat and so of temperature increase as a consequence of electrical current running through a circuit (Joule effect) or through air following its ionization (electric arc).

The Joule effect causes a temperature increase in the conductor which is proportional to the square of the current passing through it and to the circuit electrical resistance which increases proportional to temperature. In presence of high currents in conductors, in electrical equipment or switchboards, the quantity of heat generated may lead to a temperature increase, which, if exceeds the component maximum permissible temperature, can:

- damage the insulating component up to cause a short-circuit;

- ignite the combustible material of the component or of the cable, if the ignition temperature is exceeded;

- ignite the combustible materials in the nearby of cables or inside the equipment.

So the Joule effect is a consequence of: overcurrent (overload and short-circuit); earth fault currents; localized resistance (poor contact).

In the ship garage there were an electric lighting system and a system of sockets for the supply of refrigerated trucks, so as to prevent that autonomous cogeneration groups, with combustion engines, were left on for refrigerating.

Each socket designed for the purpose mentioned was connected to an electrical switchboard. During the second inspection, only one of the two switchboard control rooms could be visited, the second room was indeed made inaccessible by the event. The electrical switchboards in the visited room had no signs of damage the position of switches was not helpful for the investigation. ***Taking into account the "closed" position of the switches at the main switchboard, the possibility that a defect in the electric system may have caused the fire can be excluded.".***

f) ***Abnormal functioning of devices consuming electricity:*** in the garage, the only devices consuming electricity are placed on trucks, which, for different needs (for ex. refrigerators supply), shall be connected to a power supply.

In case of malfunctioning of even just one of the devices (consuming electricity), or of overload current or of short-circuit, the switches in the switchboards would have moved, however, as said before, some of these were not checked, as the second room was inaccessible.

In addition, a fire can often be triggered by surface pollution and tracking. Each environment is indeed subject to pollution (particles, fine dust, etc.), these substances deposit even inside electrical equipment and, together with humidity in the atmosphere, may generate a conductor pathway on the surface of insulating components. In such cases, a small current may arise and alter the material insulating properties up to the tracking and to the generation of an electric arc ("tracking" or "track"). The phenomenon of tracking involves the plastic materials used for the insulation of electrical equipment.

In any case, the malfunctioning of even one of the devices consuming electricity (ex. in case of overheating), could have provided the truck with enough heat to trigger the fire. ***So, this typology of cause is to be considered highly probable.***

The analysis made shows great uncertainty around the fire origin and cause (points a, e, f) which is also due to great destruction caused by the fire and high temperatures.

The missing or, anyway, non-effective extinguishing action has caused all the combustible materials on deck 4 to be affected by the fire, has enabled the propagation of fire to the deck below and all the decks above, as a consequence the temperatures reached were very high and so they remained for a long time.

Having said the above, although the possible fire causes were analysed, although we reasoned by exclusion and among the possible causes the following ones have been identified:

- abnormal functioning of gas-powered machineries;
- defect in n the electric system;
- abnormal functioning of devices consuming electricity;

each cause can be hardly investigated and, in such conditions, also the semiotics of fire, isn't helpful in determining the point of origin.

So the study moved on with a different method, aimed at analysing the event which occurred, assuming a potential ignition and analysing its evolution. Lastly the criticalities encountered in managing the emergency were analysed and possible plant/management solutions to mitigate the fire effects were identified.

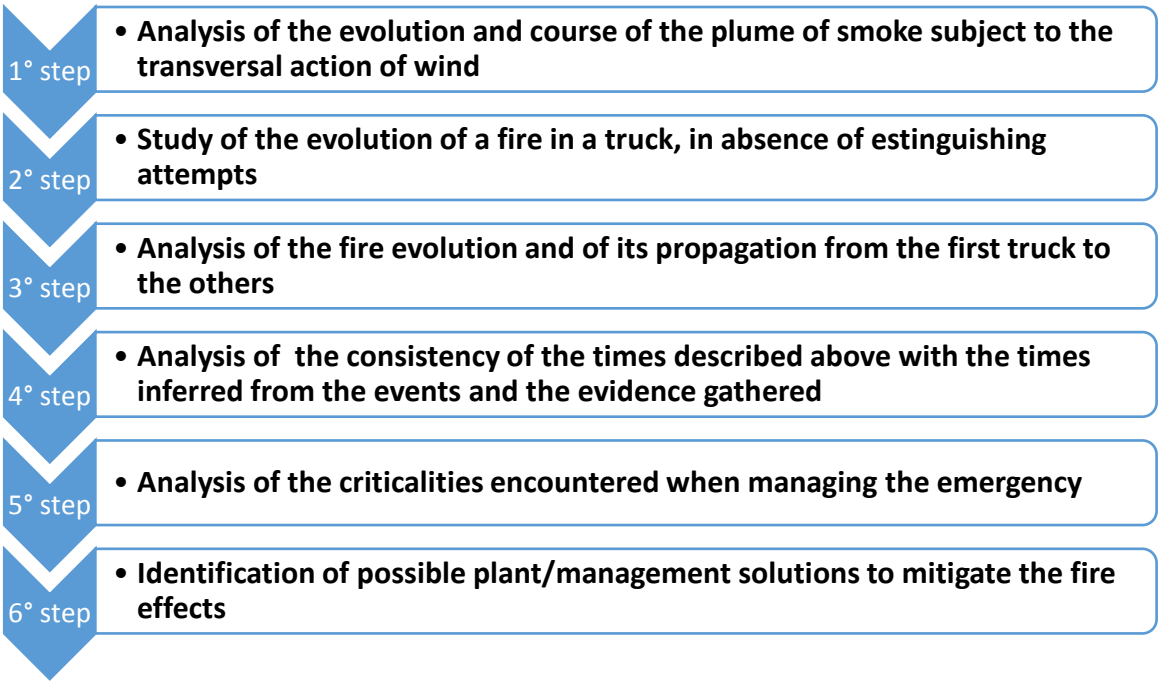


FIGURE XX STEPS OF THE STUDY

4.5.2 Analysis of the fire evolution.

Finding the fire's possible origin point

From the information collected by the personnel of the Spanish Civil Guard that intervened, during the stowage of the ship in the port of Palma, according to the testimony of some lorry drivers, in the bow area of Deck 4 one of the lorries was showing problems with the connection of the electric system of its refrigerated room.

Therefore the operational data were obtained and downloaded from the cooling devices of the refrigerated trailers with a GPS system (Annex 5); from these it was possible to find that the cooling system of the refrigerated trailer with serial number R7404BCP, hooked to the cab by the brand RENAULT with serial number 8070-BHF, shows intermittent functioning and in particular there are some disconnections/connections between the time 11:35:54 and 11:37:50 on 4/28/15, which could match the testimonies mentioned above.

Photo 7: trucks damaged by the fire

The area where the origin point of the investigated fire is has been determined based on the collected information and evidence, therefore allowing for the reduction of the area to be analysed and the confirmation of the alarms registered on the VDR.

In particular:

The data obtained from the statements made by the ship's Captain and crew and from the information provided by the company's superintendent on 1 July 2015 are reported below:

- "The Chief Mate informs me that a lorry in the bow area of Deck 4 is on fire" (Captain)
- The Engineer Officer informs me that he saw flames among the smoke. "There was a small flame, starboard, between the rows (aisles) 3 and 4, second or third position" (Chief Mate)
- "I think that the exact point of origin of the fire is between the third and fourth aisle on Deck 4. I don't know the cause of the fire. The smoke was coming out at approximately half a meter from the ground, from the higher part of the reefers tyres and in an ascending manner from bottom to top. In the lower part of the tyres there was no smoke" (Chief Engineer Officer)
- The alarm of one of the smoke detectors of the fire system placed in the bow area of Deck 4 rang at 11:45 on 28 April 2015.
- Among the interviews collected, a member of the crew stated that the sensor that got activated was sensor n. 0009 of Deck 4. The abovementioned sensor is on the starboard side at the level of frame n. 168
- Moreover, the sailor that went to verify the fire alarm reported that the fire was at the level of frame n. 168

Study of the more significant fire marks (FM) showed by the wrecked ship:

From the study of the external FM of the wrecked ship it can be clearly understood that the origin area of the investigated fire is inside the ship, in the space bounded by the front windows of Deck 4, the boarding stations on both sides of Deck 5, the front border of the external deck intended as heliport, the bow-oriented door of Deck 4 and the bow-oriented windows of the restaurant and bridge. From the study of the internal FM of the wrecked ship it can be understood that the origin point of the investigated fire has to be in the smaller base of the heat cone, formed by: the collapsed area of the roof of Deck 4 and the bow's superstructure, the space bounded by the right front corner of the courtyard with armchairs, by the segment of the main corridor that connects the entrance hall to the restaurant and by a space with compartments placed on the right of the abovementioned corridor, where there are the toilets and the kitchen, a space that has completely collapsed on the vehicles parked in the first rows of aisles 3, 4 and 5 of the car park in the Deck 4 of the ship.

Once the area that has been touched by the fire the most had been found within Deck 5, it was then cleared out and cleaned; this allowed us to find how the floor of Deck 5 shows intense fusions due to the heat, with loss of material of the steal plates that form it, at the level of the entrance to the restaurant (bow area) and the front side of the courtyard with chairs (close to the ship's entrance hall); this allowed us to see, through the holes caused by the fusion of the floor's plates, the fire-damaged remains of the vehicles parked in the front rows of aisles 2, 3 and 4 of the car park in the ship's Deck 4.

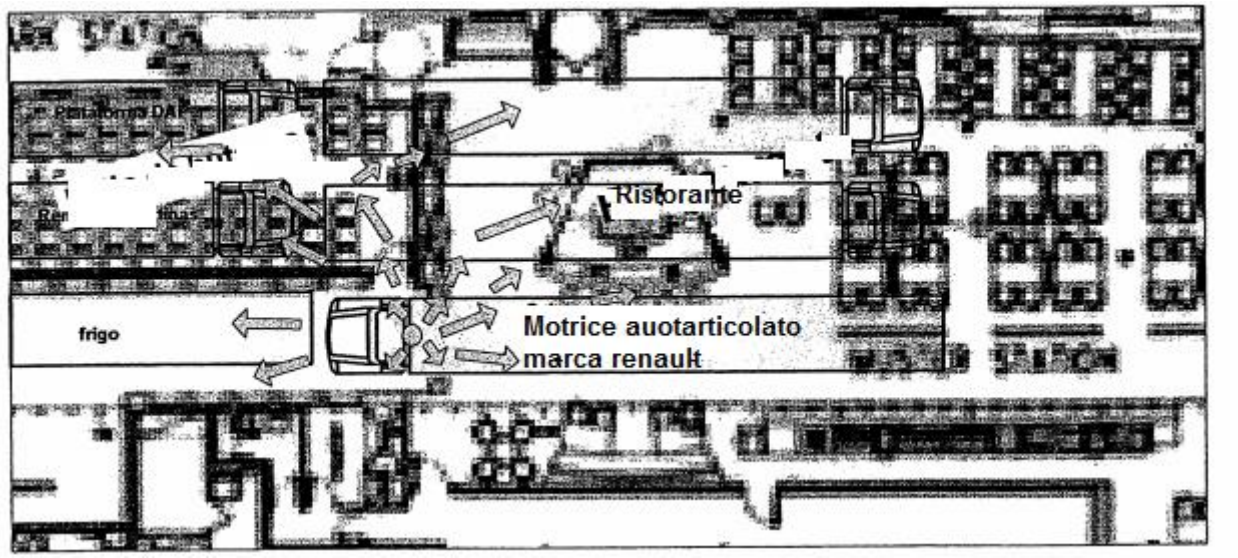


Figure 5: Position of the cab of the reefer by the brand Renault, with respect to the floor of Deck 5.

Later the fire marks (FM) and the deformations due to the heat found in the ship's structures, the right front corner of the metal walls of the room with the armchairs, the access area to the restaurant and the left side was of the kitchen, as well as the furniture in the room with the armchairs and the restaurant, were analysed in detail.

Moreover, the following actions were taken:

- Mark and identify on the ground of Deck 5 the rows and aisles of the left front area (bow-port) of the car park that occupies the entire Deck 4.
- Create cuts in the ground of Deck 5 in order to be able to determine the position and characteristics of the vehicles parked in aisles 2, 3 and 4 of rows 2 and 3 of the car park in Deck 4.
- Examine in greater detail the fire's origin area in order to be able to determine the origin point of the vectors of propagation of the fire itself.

The works and studies carried out have allowed for the restriction of the origin area, now limited to the space bound by the back facade of the cabin of a cab parked facing the bow, in row 2, aisle 4 of the car park in Deck 4 and the front facade of the refrigerated semi-trailer hooked to it.

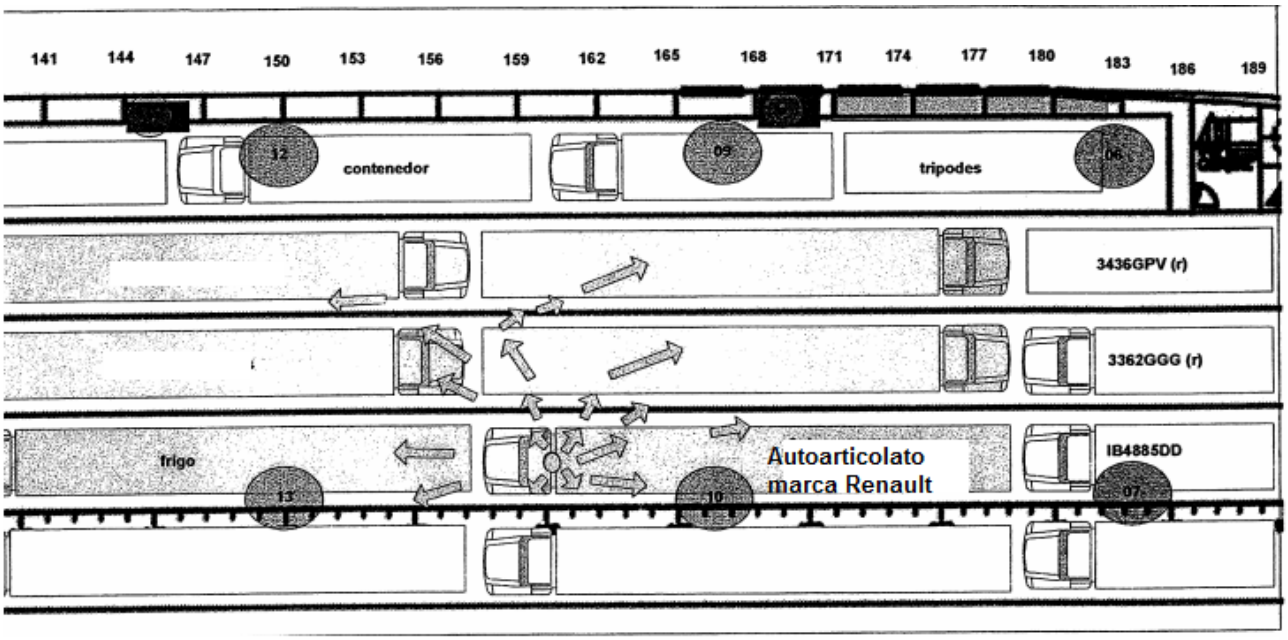


Figure 6: Position of the reefer, brand Renault on Deck 4

The only identifying elements of the lorry's cab that could be found – due to the state it was in – were the identification code and number placed in one of its bushings, the one corresponding to its left back tyre; after several consultations, it was then found that the aforementioned number only identifies the brand of vehicle, which in this case was a cab by the brand Renault.

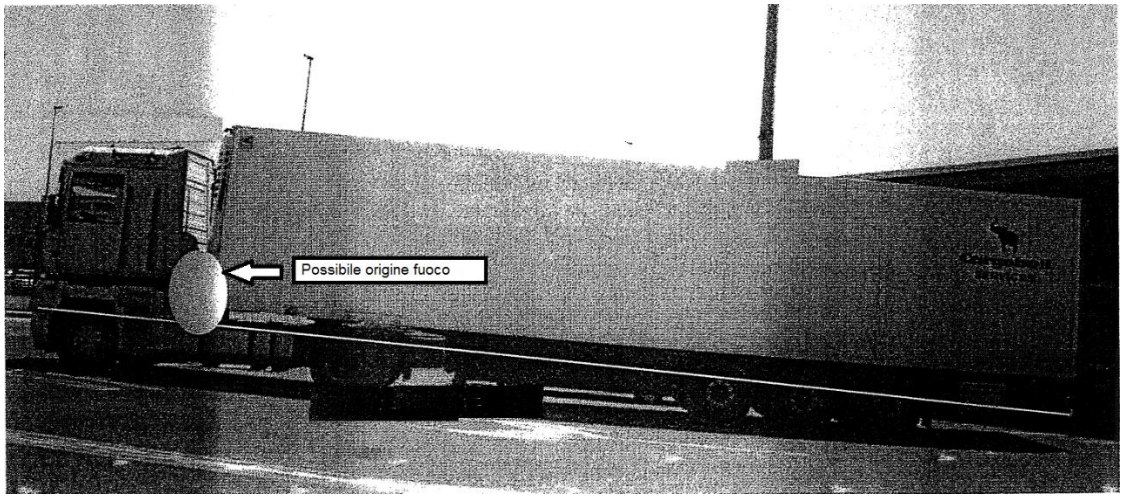


Photo 9: Similar reefer truck

With regards to the trailer, from the remains that were found (glass wool, bones and meet) it was possible to understand that it was a refrigerated trailer transporting meat.

5. CONCLUSIONS

5.1 Shipboard organization

The SMS management manual of the GRIMALDI DEEP SEA S.p.A., for the parts applicable to the M/V SORRENTO and the related procedures are structured almost in the same way as in other ship companies and naval units, and the procedures therein included are in line the regulation.

Anyway, it can be stated that the Manual being examined included detailed and well defined procedures for the various emergencies and that overall they appeared to be correctly followed by the crew belonging both to the charterer and the Ship Owner.

5.1.2 Inspections on garage decks and patrols during navigation

Although the general management of the operations on the ship seems to be performed overall safely, a review of the SMS procedures related to the inspection on garage decks and patrols during navigation, is to be evaluated, with more frequent internal audits to check the implementation of the operational procedures established and/or a specific training by the Company for the staff in charge of these operations, clearer procedures for loading - lashing - socket connection operations. Similarly a review of the way patrols during navigation are performed should be considered.

5.1.3 Emergency management

The emergency in general has been managed in a proper and effective way. In particular, despite the very serious situation, the ship's Captain was able to easily coordinate the crew and the various stages of the emergency, by abandoning ship in a short time and without consequences for the passengers and personnel on board.

5.2 Fire

5.2.1 Fire detection and considerations on insulation

The fire was detected by sensors belatedly, due to the technical issues described above, with particular reference to the presence of side openings, which, combined with the wind blowing in that area, enabled fire to develop so much that, when it was finally detected, it could no longer be kept under control either by the firefighting team or by the Drencher system, because interesting a too large area of the garage. In addition, the CCTV systems available did not provide a complete overview of the area, because, as established by the regulation in force, they were installed

exclusively for the purpose of checking the unauthorized accesses in that rooms, mainly for security reasons, as well as to observe vehicle movements in adverse weather conditions.

With reference to the level of insulation (or fire resistance) of the area specifically designed for rescue means, if compared with the surrounding spaces, the following considerations can be made: - it is compliant with the provisions established by the applicable laws; - the regulation of the SOLAS Convention II-2/3.1 defines the A class divisions as follows: *"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 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.....omissis....*

So an A-60 class division (which is the highest level of resistance to fire for a ship division) may have, from time 0 of a fire start, an average temperature of 140° C on the surface which is not directly exposed to flames (with peaks of 180°C).

Such a temperature certainly prevents a correct use of devices (such as rescue and life-saving equipment) close to the areas affected by fire.

5.2.2 Containment

As highlighted in the declarations made, the fire-fighting team and those making the patrols could not reach and easily move in the garage, because the fire was of huge dimensions and, furthermore, as reported in some interviews, the F-team, faced difficulties for entering the garage area because of the distance between the vehicles that - even if in compliance with regulation - can become narrower when wearing firefighting suits/equipment.

The Drencher was opened in the wrong area and for four areas, furthermore, after few minutes it became unusable, as the main power supply disconnected – probably because of the damage caused by fire to the exposed cables on the ceiling of deck 4. In such conditions, the Drencher system could be powered only by the fire-emergency pump, which, however, didn't provide enough water to effectively extinguish fire.

Similar situations were found also during the investigation of the Norman Atlantic.

5.2.3 Extinction

As it was reported in the simulations carried out during the investigation of the Norman Atlantic, in this case it can also be said that, the fire reached rapidly such heat release and temperature levels that any intervention of the fire-fighting teams was useless.

In other words - notwithstanding “Sorrento”, her system and its control apparatus are, pursuant to the norm, fully compliant with the regulations in force - the system (in this case by “system” the interaction between the extinguishing Drencher system, the related control system, the activation by the staff in charge, is meant) was insufficient to fight a fire of such amplitude.

5.3 Propagation, fire origin and structural criticalities

The study and the simulations made to analyse the evolution of the fire which affected deck 4 of the M/V Sorrento have highlighted the following event features:

- fast propagation;
- high quantity of smokes produced;
- high temperatures;

and the following causes and factors which certainly worsened such effects:

- long time elapsed between fire detection, warning and manual extinguishing;
- High response time of active protection systems;
- High fire load;
- Close distance among combustible materials;
- Much ventilation;
- High compartment volumes;
- Absence of vertical compartments.

The factors above have therefore caused a fire with a very fast time/temperature evolution.

As already analysed in this report, the declarations and information gathered show that the time elapsed from the first detection to the general warning of Fire Alarm with following Drencher activation order to the Engine Room was, highly probably, of about 20 minutes. The fire development time from its ignition is around 30-35 minutes.

The study has indeed proved that the smoke generated started to significantly come out of the side windows well before.

In addition, the congruence between what emerged from the study and from the crew members’ declarations can be found also in the description of the flames coming out of the windows: “*when I went back to the navigation bridge, after few minutes, I could see a red/pink flash, so I looked at the starboard, where I could see open flames coming out of the first three windows on the forward side as if they were “launched by a flamethrower” and I really couldn’t understand why, because the trucks, although there was much wind coming from the left, acted as a protection. Immediately after, the FIRE ALARM rang (serious fire)”.*

The quantity of materials burning increases indeed enormously over time, as well as the production of smoke and warm gases. As the room ventilation depends on the openings towards the outside (ventilation factor), in that situation, where the direction and strength of wind was also a crucial element, the openings available for letting fresh air come in were reduced, as they were obstructed by smoke. In this way the quantity of fresh air available for combustion decreased, unburned pyrolysis gases left the compartment together with smokes, when they were close to the openings, they found enough oxygen to burn and generate the usual flames coming out of windows, as it normally happens when the fire is in the generalized or *postflashover* step.

5.4 Evacuation

Contrary to what happened during the fire on board the M/N Norman Atlantic, in this case the evacuation was conducted rapidly and without consequences for the passengers and crew.

5.5 Action Taken by the Company

As provided for in the SMS procedure, the DPA later conducted the preliminary analysis of the accident so as to order the corrective actions to be taken in the immediate aftermath, with communication on the 04/30/2015. These measures have been confirmed after the end of the internal investigation on the accident on 10/21/2016.

The communications and the measures that were adopted should be considered adequate and timely.

5.6 Considerations on the condition of reefer trucks

The investigation report of the Civil Guard of Palma de Majorca filed the investigation as an accident and, as mentioned before, it ascribed the fire's cause to the malfunctioning of the cooling system of a refrigerated truck.

As already highlighted in the investigation report of the M/V Norman Atlantic, the reefer trucks that remain in operation in the garage areas during voyage are considered a serious fire risk which has been identified by relevant studies[2] and it is well known to the crew members of Ro-Ro vessels. On the matter, the applicable EU and International legislation is:

[2] *1. IMO Working Document FSI 21/5 – Report of the Correspondence Group on Casualty Investigation, 28-11-2012*
2. IMO Working Document SSE 2/INF.3 - Transport of electric vehicles and vehicles with refrigeration units on board ro-ro vessels

- Council Directive 77/143*"on the approximation of the laws of the Member States relating to roadworthiness tests for motor vehicles and their trailers"*, as amended,
- COUNCIL DIRECTIVE 96/96/EC *"on the approximation of the laws of the Member States relating to roadworthiness tests for motor vehicles and their trailers"*, as amended,
- The UN Treaty "*Agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to be used for such Carriage" (ATP Agreement).*

However, even if according to the legislative framework in force, reefer trucks have to comply with the ATP agreement requirements and be inspected every 6 years and certified, such controls do not include a specific inspection for their refrigerating units and their electrical equipment (power supply plugs and cables etc.) in terms of ascertaining their good condition and safe operation. The same stands also for the internal combustion engines of the reefer units which although are not permitted to operate during voyage, they can start automatically when the power supply from the vessel is lost due to a problem. Consequently reefer trucks are permitted to be loaded on Ro-Ro vessels and remain in operation during voyage without any solid evidence that they have been properly maintained and inspected in order to assure that they will not pose a risk to the vessel. The only measures that can be applied by the crews to mitigate the risk from the operation of this equipment are to perform a macroscopic inspection and most probable an electrical check on the plugs before they are connected to the vessel's power.

A periodical inspection/certification, aimed to verify the safe working conditions of the refrigerating units installed on the reefers followed by controls carried out by ticketing offices - at the moment of ticket purchase - of the validity of related certifications would increase safety.

It is worth, according DIGIFEMA, to issue a special safety recommendation addressed to the European Commission that takes into considerations the possibility to amend the related regulatory framework..

6. RECOMMENDATIONS

6.1 COMPANY

6.1.1 GRIMALDI DEEP SEA S.p.A.

004/2015-01 Integrating the existing procedures to improve the efficiency and effectiveness of patrols in the deck garages, particularly before the ship departure;

004/2015-02 Re-evaluate the frequency of *internal audits* aimed at checking the compliance with the applicable regulations and procedures, particularly with regard to stowage, lashing and connection of *reefer* sockets;

6.2 IMO

004/2015-03 A study / analysis shall be carried out to develop solutions, which are different from the existing ones, concerning the aspects and structural/constructive criticalities mentioned above:

- Fire detection systems in the deck garages, which, considering the openings in the hull, shall be placed and designed/calibrated pursuant to the openings;
- Side openings of open cargo decks of ro-ro ships, to prevent/mitigate the devastating effects produced by the uncontrolled inflow of external air;
- Review of fixed fire-fighting systems protecting garages on decks, the implementation of alternative extinguishing/containment systems (Ex.: water barriers/water mist etc..) is recommended;
- The passive protection of cables and electric circuits running through the garage shall be improved so as to extend the activity of emergency systems;
- Obligatory installation of an adequate video surveillance system (equipped with temperature detectors) in the garages so as to enable a continuous and immediate remote control (navigation bridge, ECR, etc.);
- For the existing ships, evaluate the redundancy of electric systems supplying the pumps for the fixed extinguishing system of “Drencher” type so as to ensure the full operation of the system also in emergency conditions;
- FSS code, chapter 9 – par. 2.3.2.1, should be amended in order to include also the technical specifications for smoke detectors to be installed inside open ro-ro cargo spaces.

004/2015-04 Integrating the possibility to record in the VDR the audio data originating from ECR and including, among the registered data, the whole set of alarms recorded by the fire detection system;

004/2015-05 Implementing software for VDR of standardized and *open source* type and upgrade the applications used for data playback;

004/2015-06 The minimum distance among the vehicles lashed in the garage and for enabling the operational and safe passage of the fire-fighting team on board shall be established;

004/2015-07 Providing in advance, while considering the ship operative nature, a detailed list of the cargo which shall be loaded, including also sizes and weight and any further technical requirements (for ex. electrical connection on board etc…) so as to enable the compilation of the cargo plan before departing;

6.3 EU COMMISSION – IMO

004/2015-08 According to the criticalities evidenced at para 5.8, EU COMMISSION and IMO are invited to consider a review of the rules/legislation applicable to the reefer trucks and the refrigerating units installed on-board.

7. ANNEXES

1. MSM
2. crew list
3. SMS 5.3.1
3. ship's certificates
4. list of operational data obtained and downloaded from the cooling devices of the refrigerated trailers with a GPS system