BEST PRACTICES FOR THE

TRANSPORT OF ELECTRIC VEHICLES

ON BOARD VESSELS

JUNE 2022

TABLE OF CONTENTS

EXECUTIVE SUMMARY

ABS is a leading classification society with a mission-based focus on promoting security of life and property, and preserving the natural environment. Over the past few years, ABS identified the increasing concern with vessels carrying electric vehicles (EVs) such as hybrid electric, plug- in hybrid electric, and battery electric vehicles. As a result, workshops were conducted to identify the best practices associated with transport of these vehicles on board vessels. The participants were requested to complete a survey prior to the event to facilitate discussion. The best practices identified during the workshop include:

VEHICLE STOWAGE

- On Pure Car Carrier (PCC)/Pure Car and Truck Carrier (PCTC) vessels, EVs should be located in a designated area.
- Damaged vehicles should be located in a designated area; this should be on the weather deck where available.

CHARGING

- Only ship-owned cables and connectors should be used in charging operations.
- Charging should only be from power sockets designed and approved for charging purposes. Such sockets are to be capable of being disconnected from the shipboard power system at a location accessible if the vehicle being charged is on fire.
- Charging operations should not be carried out during cargo loading/unloading.

FIRE DETECTION

- A video monitoring system should be installed to supplement the fire detection system for cargo areas intended for the carriage of EVs. The intent is for early location identification and early activation of the applicable firefighting system.
- Fire patrol frequency should be increased for areas carrying EVs.
- Portable thermal imaging devices should be provided and used by the crew performing patrols in a roll on/roll off (ro/ro) cargo space containing EVs.

CREW TRAINING

- Training should be provided for crew who may respond to a fire involving EVs. Crew involved in firefighting should be capable of recognizing EVs, understand the risk posed by high voltage equipment in EVs and be aware of the possible release of toxic gas.
- The crew involved in patrolling areas containing EVs should be provided with and trained on the use of thermal imaging cameras.

FIREFIGHTING

- Fixed water deluge or mist system should be provided to cover the areas that carry EVs. A fixed monitor system can be used in open deck areas.
- The drainage system is to be sized to remove no less than 125 percent of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles. Drainage systems should also be routinely inspected to avoid blockage of the drainage opening. Operation of valves on the drainage system should be operable from an accessible location in case of fire.
- For EVs which are charged on board ferries, the ship's electrical supply to the vehicle should be cut prior to attempting to fight a fire, to reduce the potential of electric shock.

SPECIAL CONSIDERATIONS

- Water lancing equipment should be provided for all vessels carrying EVs and easily accessible for vehicles stored in containers.

The best practices summarized within this report apply to ro/ro vessels including passenger-carrying vessels and are intended to complement but not replace ship operators' existing measures for the carriage of EVs and are applicable per the configuration of each vessel.

METHODOLOGY OF BEST PRACTICES

1 INTRODUCTION

With the introduction of recent technologies in the automotive industry, there has been an increase in the number of electric vehicles (EVs) being manufactured. Within the past 10 years, EV sales went from an estimated 100,000 to 6,750,000 with a 108 percent increase from 2020 to 2021 alone. It is projected to increase within the next 10 years (Irle, 2021).

EVs have become an area of focus for the maritime industry as there have been increased fire incidents on vessels transporting these vehicles. It has been identified that there is a need for a collective best practice set. As a result, on April 27 and 28, 2022, ABS hosted virtual workshops where representatives with experience in the transport of these vehicles were invited to participate and share their experiences and best practices. Attendees in the workshops represented car manufacturers, shipowners, ship operators, flag States, P&I Clubs and independent consultants. To help focus the discussion and drive the agenda, the workshop participants were asked to complete a pre-workshop survey that queried best practices used in transporting EVs at sea.

The best practices summarized within this report apply to roll-on roll-off (ro/ro) vessels including passenger-carrying vessels and are intended to complement but not replace ship operators' existing measures for the carriage of EVs and are applicable per the configuration of each vessel.

As the leading classification society, ABS' broad experience affords the opportunity to participate in the most innovative projects collecting and applying best practices to industry activities. In support of the ABS mission, this report is an example of how ABS, as a classification society, facilitates communication among stakeholders and shares that experience with the industry, fostering a broader conversation that supports the adoption of new tools, systems and practices that improve safety.

2 OVERVIEW

2.1 OBJECTIVE

Virtual workshops were conducted to collect industry best practices associated with the transport of electric vehicles (EVs) on board vessels. The intention of this document is to publish collected data to mitigate risks involved with the transport of EVs in the maritime industry.

These best practices provide baseline guidance for the transport of EVs. They are not intended to replace any standards or requirements for the carriage of EVs that currently exist, or which may be developed in the future.

2.2 DEFINITIONS

For this report and during the workshops, the definition of "electric vehicle" refers to vehicles powered by lithium-ion batteries or similar which include the following:

- Hybrid electric vehicles;
- Plug-in hybrid electric vehicles; and
- Battery electric vehicles

Roll-on/roll-off (ro/ro) vessels also include the following vessel types associated with rolling cargo:

- Roll-on/roll-off passenger vessels (ro/pax, ferries)
- Roll-on/roll-off and container vessels (ConRo)
- Pure Car Carriers (PCC)/Pure Car Truck Carriers (PCTC)

2.3 WORKSHOPS

ABS held virtual workshops with the global attendees representing:

- Car Manufacturers
- Vessel Owners
- Vessel Operators
- Vessel Management Companies
- Flag State/Regulatory Bodies
- P&I Clubs
- Independent Consultants

3 CURRENT RESEARCH AND INDUSTRY BEST PRACTICES

3.1 RECENT RESEARCH

In recent years, significant research has been completed regarding the design and safety performance of batteries and electric vehicles (EVs). This section addresses recent applicable research.

IMO SUBCOMMITTEE ON SHIP SYSTEMS AND EQUIPMENT SUBMISSION PAPERS 7/6/6 AND 7/INF.11

Research and testing were completed on Nickel Manganese Cobalt (NMC) and Lithium Iron Phosphate (LFP) batteries. These tests were conducted in an enclosed space in which the batteries were positioned in a mock-up of a vehicle located in the middle and rear chassis position. The results of these field studies were presented to the International Maritime Organization (IMO) and were taken into consideration prior to creating the best practices reviewed in the workshops.

Carbon Dioxide

- Four fire tests (two NMC and two LFP) were conducted, to test the performance of carbon dioxide (CO_2) as a fire-extinguishing medium. For the four tests, the initial flames were extinguished successfully however large amounts of smoke were released causing low visibility. The temperature of thermocouples placed on the test battery pack decreased initially, however three out of the four battery packs reignited shortly after all CO_2 medium was used. The result was that the CO_2 medium did not prevent thermal runaway from occurring post-application.

Heptafluoropropane

- Four fire tests (three NMC and one LFP) were conducted with the release of Heptafluoropropane as the fire-extinguishing medium. The results were like the CO_2 release. The initial temperature drop was seen, with low visibility and the fire was fully extinguished. The reignition of the battery packs occurred however as thermal runaway was not prevented.

Aerosol

- Three fire tests (two NMC and one LFP) were conducted with the release of aerosol fire-extinguishing medium. The results were like both the CO_2 and Heptafluoropropane with flame extinguishment, low visibility and a temperature drop; however, reignition occurred shortly afterward. Thermal runaway was not prevented.

Pressure Water Mist

- Five fire tests (three NMC and two LFP) were conducted with the release of pressured water mist as the fire-extinguishing medium. With all five tests, similar initial conditions were seen compared to the other tests completed. However, the battery packs did not reignite post activation of the system release. The battery packs were damaged by the water and visibility was low. Thermal runaway was prevented for these tests.

Low-Expansion Foam

- Four fire tests (two NMC and two LFP) were conducted with the release of low-expansion foam. The flame was not initially put out however the battery pack did have sufficient cooling by the foam to prevent reignition. Cooling and smoke occurred with a temperature drop seen by the thermocouples. Based on the research published, the foam indicates increased thermal conductivity of the liquid agent, which may cause short circuits and electric sparks during the fire-extinguishing process which may pose additional safety risks after the fire has been extinguished.

BEST PRACTICES FOR EMERGENCY RESPONSE TO INCIDENTS INVOLVING ELECTRIC VEHICLES BATTERY HAZARDS: A REPORT ON FULL-SCALE TESTING RESULTS, THE FIRE PROTECTION RESEARCH FOUNDATION

Research was completed by the Fire Protection Research Foundation involving EV battery hazards. A free burn, unsuppressed high heat rate test of a standalone battery pack, and a full-scale suppression test for a battery pack in a mock-up vehicle were conducted. The full-scale fire suppression testing performed included the following data collection:

- Temperatures;
- Heat fluxes;
- Projectile observations;
- Suppression water sampling;
- Volume of suppression water flow;
- Nozzle voltage and current measurements;
- Chassis voltage and current measurements;
- Battery internal temperatures;
- Battery internal cell voltage measurements;
- Thermal imaging;
- Still photography;
- High-definition video; and
- Firefighter observations.

Based on the testing of the full-scale setup, it was concluded that the water may not be sufficient in achieving full extinguishment but serves as a medium to reduce heat and cool the battery as thermal runaway subsides or is prevented by the application of water.

ALTERNATIVE FIXED-FIRE EXTINGUISHING SYSTEMS FOR RO/RO SPACES ON SHIPS (FIRESAFE II), EMSA

Research was completed by the European Maritime Safety Agency (EMSA) to identify the effectiveness and alternatives to a drencher system for firefighting purposes. Two main alternative fire-extinguishing systems were studied in the report to be compared to the performance of a deluge water spray system design in accordance with Resolution A.123(V) (existing ships) and a system designed in accordance with MSC.1/Circ. 1430 (ships constructed after 2012). The tests performed simulated a partly shielded and partly exposed fire in a freight truck trailer with a setup to simulate an actual fire suppression system installation. The testing setup was not specific to EVs, however. The results of this study were considered prior to the creation of the best practices that were reviewed in the workshops.

Compressed Air Foam System (CAFS)

- For this system, two tests were conducted with a discharge density of 2.4 mm/min. The two tests were terminated due to the limited fire suppression seen. The system performance was due to the low discharge density, which was significantly less compared to the other systems.

Foam-water Spray System

- For this system, the foam-water spray (6.5 mm/min+foam) limited the fire size to some extent. The performance of the foam-water spray indicated limited signs of improvements due to the foam additives.

Deluge Water Spray System

- For this system, the deluge water spray test designed in accordance with MSC.1/Circ.1430 indicated the most successful results. Fire size, cooling and control capabilities would likely prevent spread.

3.2 2022 ABS RO/RO ELECTRIC VEHICLES BEST PRACTICES SURVEY RESULTS

Prior to the workshops, the attendees completed an anonymous survey to provide feedback on the best practices used in the industry. The following figures represent the organizations involved in the workshops.

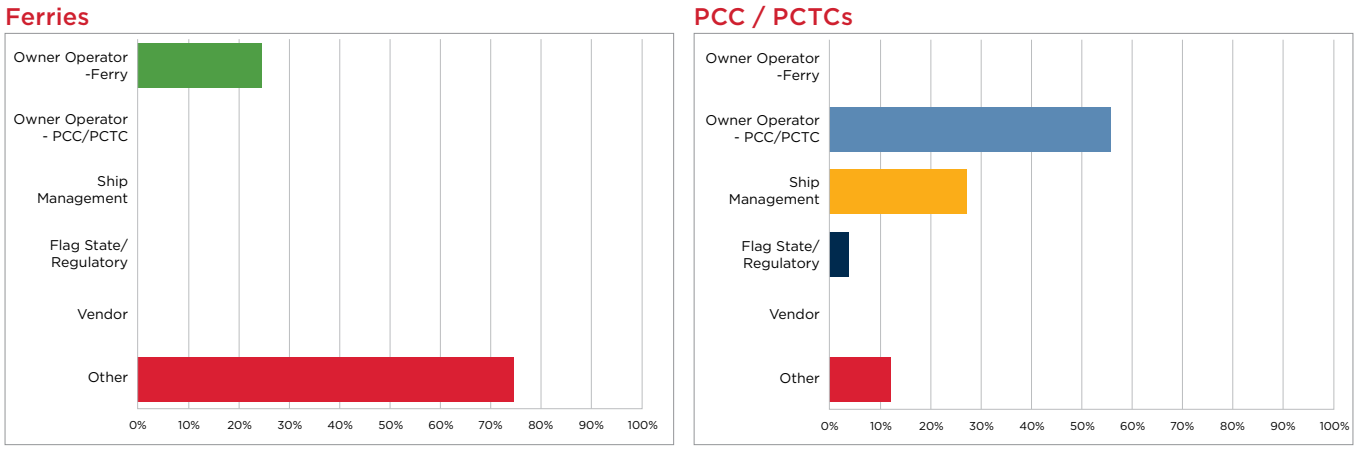

Figure 1: Survey Results – Organization Type

Figure 1 displays the organization type of the survey participants, of which 75 percent of ferry survey participants were representatives of insurance companies or independent consultants and the remaining being owner or operators. Seventy percent of the Pure Car Carrier (PCC)/Pure Car and Truck Carrier (PCTC) survey participants represented owner/operators and ship management companies. The remaining survey participants included representatives from flag State/regulatory bodies, insurance and independent consultants.

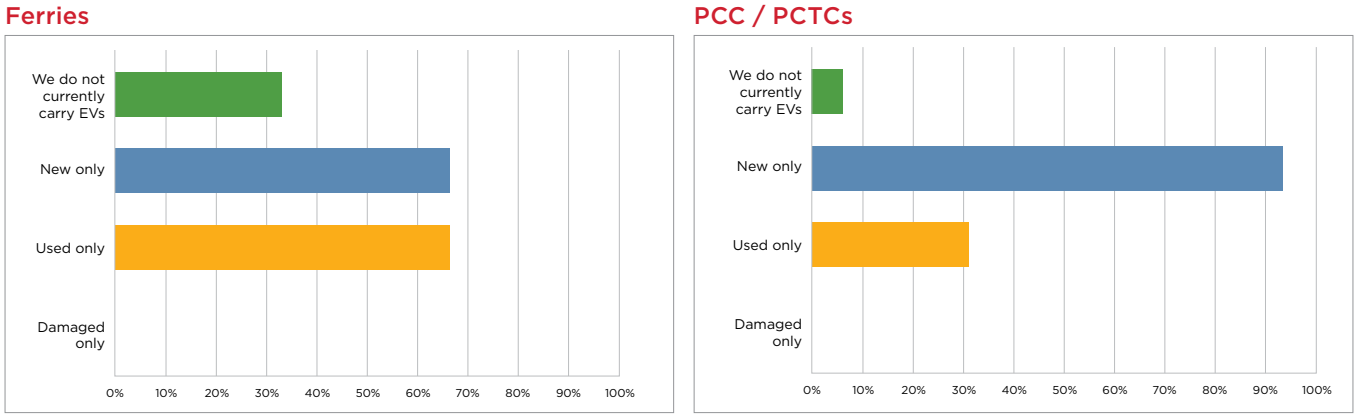

Figure 2: Survey Results – Types of Vehicles Transported

Figure 2 displays the types of vehicles transported per company represented. For the ferries, the responses were split between new and used vehicles which coincides with owner self-driven vehicles. For PCC/PCTC carriers, 94 percent of the respondents indicated that they transported new vehicles only. This information provided a basis to the workshop participants on the types of vehicles that are being shipped per vessel type.

3.3 CURRENT INDUSTRY BEST PRACTICES

The survey findings represented in the following figures summarize the best practices identified in the workshop.

3.3.1 DESIGNATED AREA FOR STOWAGE OF ELECTRIC VEHICLES

For the designated areas for stowage of EVs category, this item was presented with the intent of having the EVs in a designated area for early fire detection and appropriate fire-fighting actions. Figure 3 displays the survey results and best practices associated with this category.

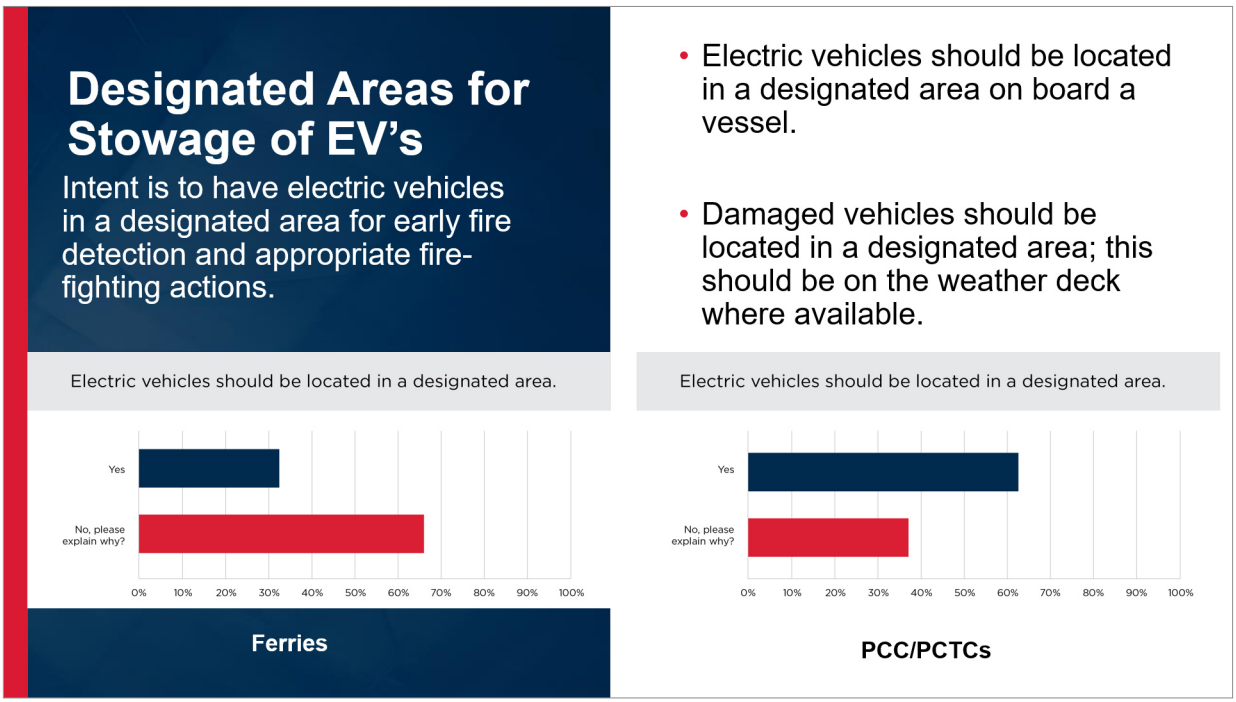

Figure 3: Designated Areas of Stowage of Electric Vehicles Category – Workshop Display

- **Best Practice: On PCC/PCTCs EVs should be located in a designated area.**

  For ferries, 66 percent of the survey participants stated that having a designated area for EVs was not needed, primarily due to the operational challenges of segregating vessels and that there is no benefit to segregating the vehicles based on their fuel type from a risk perspective.

  For PCC/PCTCs, 66 percent of the survey participants stated that EVs should be stowed in a designated area.

- **Best Practice: Damaged vehicles should be located in a designated area, this should be on the weather deck where available.**

  Fifty percent of PCC/PCTC and 67 percent of ferry survey participants stated this was an appropriate best practice. The responses that did not support this best practice stated that damaged vehicles should not be loaded or there was no weather deck configuration on their vessels.

3.3.2 CHARGING PRACTICES: FERRIES

For the charging practices in the ferries category, this item was presented to the group with the intent of identifying best practices associated with the charging of EVs on passenger-carrying vessels. Figure 4 displays the survey results and best practices associated with this category.

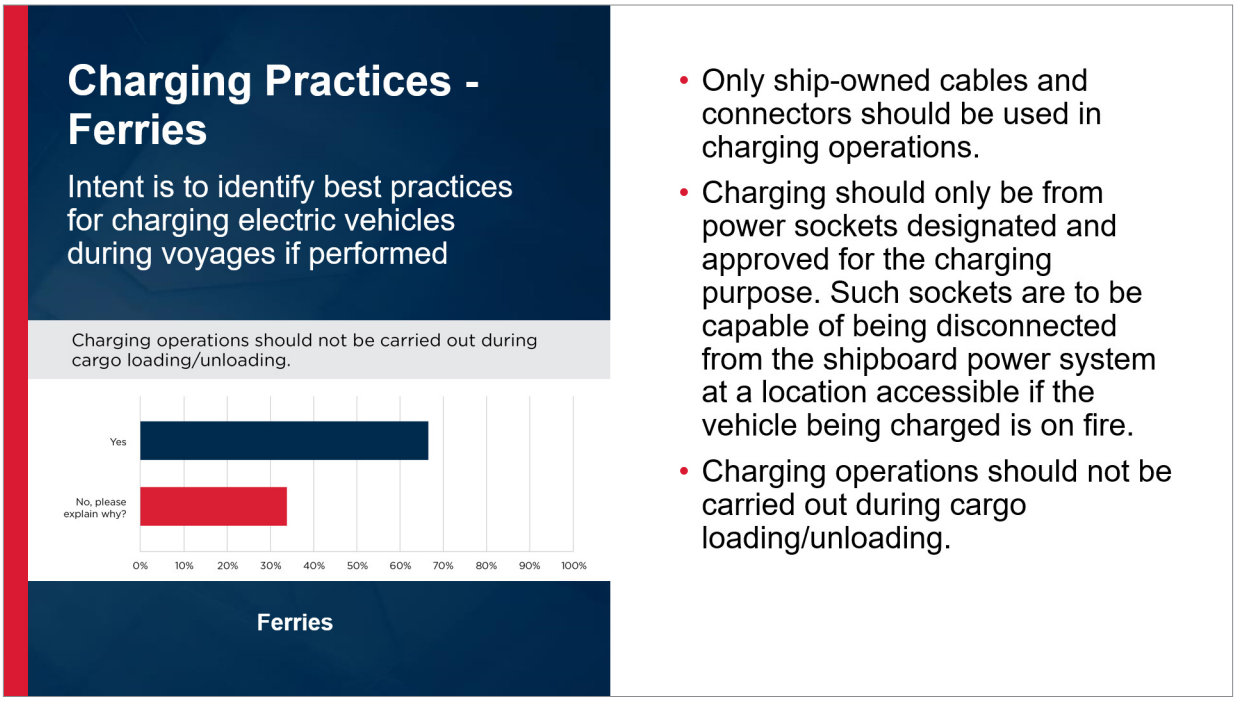

Figure 4: Charging Practices Category – Ferries – Workshop Display

- **Best Practice: Only ship-owned cables and connectors should be used in charging operations.**

  One hundred percent of the survey participants stated this was an appropriate best practice for ferries that allowed for this configuration.

- **Best Practice: Charging should only be from power sockets designed and approved for charging purposes. Such sockets are to be capable of being disconnected from the shipboard power system at a location accessible if the vehicle being charged is on fire.**

  One hundred percent of the survey participants stated this was an appropriate best practice for ferries that allowed for this configuration.

- **Best Practice: Charging operations should not be carried out during cargo loading/unloading.**

  Sixty-seven percent of the participants stated this was an appropriate best practice for the vessels carrying passengers. The remaining participants stated that all risks should be considered prior to adopting this best practice.

3.3.3 CHARGING PRACTICES: PURE CARE CARRIERS/PURE CAR AND TRUCK CARRIERS

For the charging practices on PCC/PCTCs, this item was presented to the group with the intent of identifying best practices associated with charging EVs on PCC/PCTC vessels. Figure 5 displays the survey results and best practices associated with this category.

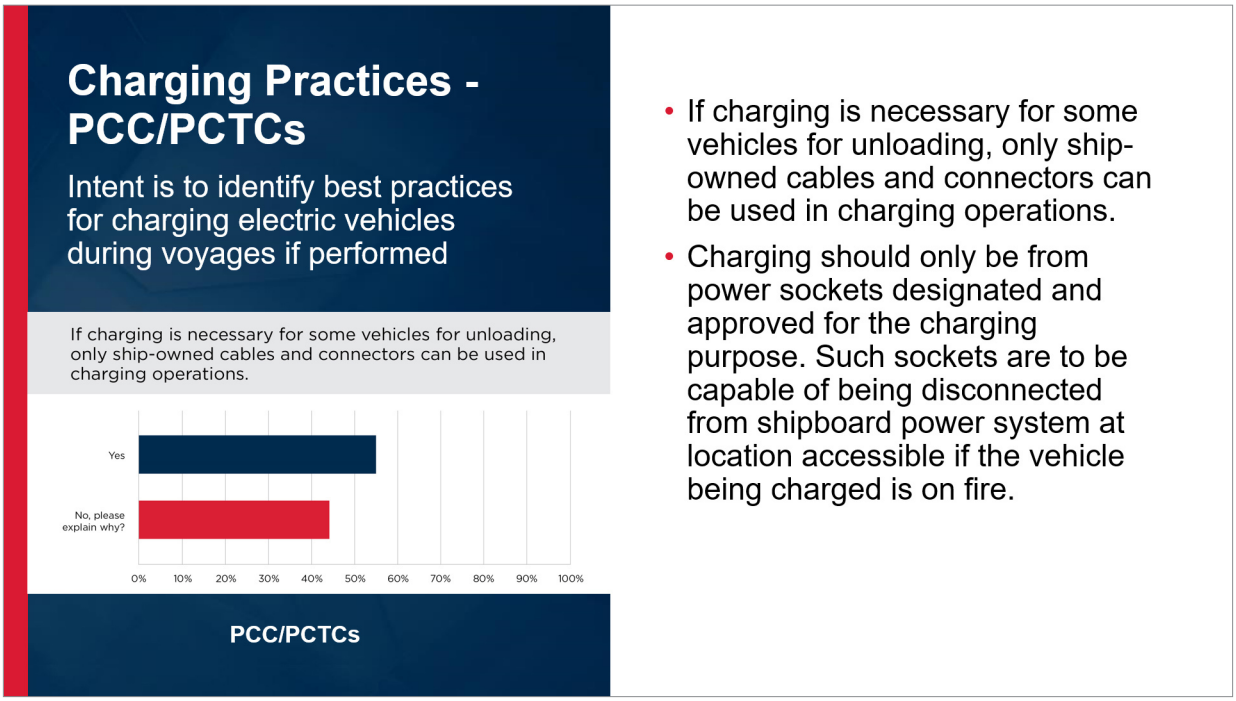

Figure 5: Charging Practices Category -PCC/PCTCs - Workshop Display

- **Best Practice: If charging is necessary for some vehicles for unloading, only ship-owned cables and connectors should be used.**

  Fifty-five percent of the participants stated this was an appropriate best practice for the vessels that allowed for this configuration. The remaining survey participants stated that charging is not conducted on PCC/PCTC vessels and damaged vehicles are towed.

- **Best Practice: Charging should only be from power sockets designated and approved for the charging purpose. Such sockets are to be capable of being disconnected from shipboard power system at a location accessible if the vehicle being charged is on fire.**

  Eighty-three percent of survey participants stated this was an appropriate best practice for the vessels that allowed for this configuration. The remaining survey participants stated that charging should not be conducted on board.

3.3.4 FIRE DETECTION

For the fire detection category, this item was presented to the group with the intent of identifying best practices associated with early fire detection for electric vehicle carriage on ro/ro vessels. Figure 6 displays the survey results and best practices associated with this category.

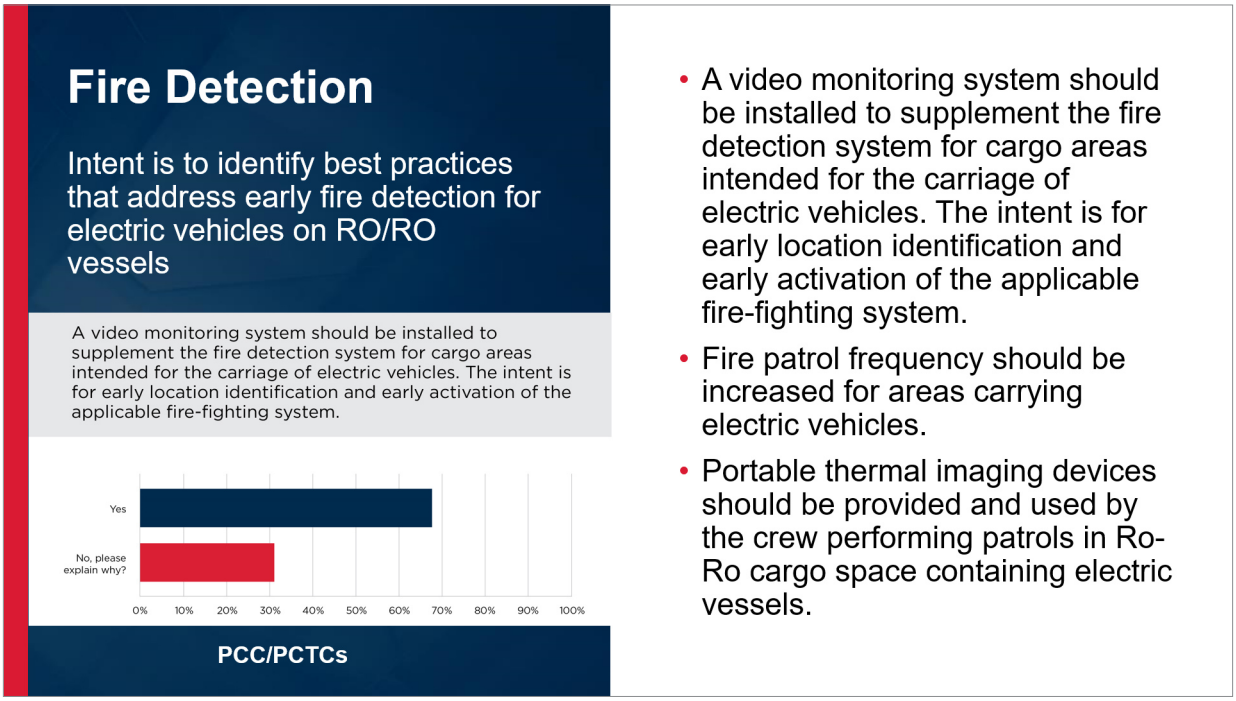

Figure 6: Fire Detection Category – Workshop Display

- **Best Practice: A video monitoring system should be installed to supplement the fire detection system for cargo areas intended for the carriage of EVs. The intent is for early location identification and early activation of the applicable firefighting system.**

  One hundred percent of ferry and 67 percent of PCC/PCTC category survey participants stated this was an appropriate best practice.

  The remaining survey participants stated that video monitoring systems do not provide any additional benefit beyond that provided by traditional Safety of Life at Sea (SOLAS)-required fire detection systems. Other responses included that thermal surveillance, smoke detectors or heat detectors would be more efficient than a video monitoring system. Twelve percent of survey participants stated that the free height between the ceiling of the deck and the top of the car would not be sufficient for any visual surveillance.

- **Best Practice: Fire patrol frequency should be increased for areas carrying EVs.**

  Sixty-seven percent of ferry and 84 percent of PCC/PCTC survey participants support this statement as a best practice. The remaining responses stated the additional patrol would lead to crew fatigue and that there is no additional risk to the carriage of EVs.

- **Best Practice: Portable thermal imaging devices should be provided and used by the crew performing patrols in ro/ro cargo space containing electric vessels.**

  One hundred percent of ferry and 89 percent of PCC/PCTC survey participants stated this was an appropriate best practice for the vessels that allowed for this configuration. The remaining responses questioned the effectiveness of the thermal imaging devices over traditional methods of fire detection.

3.3.5 CREW TRAINING

For the crew training category, this item was presented to the group with the intent of identifying the best practices associated with specific additional training for EV carriage on ro/ro vessels. Figure 7 displays the survey results and best practices associated with this category.

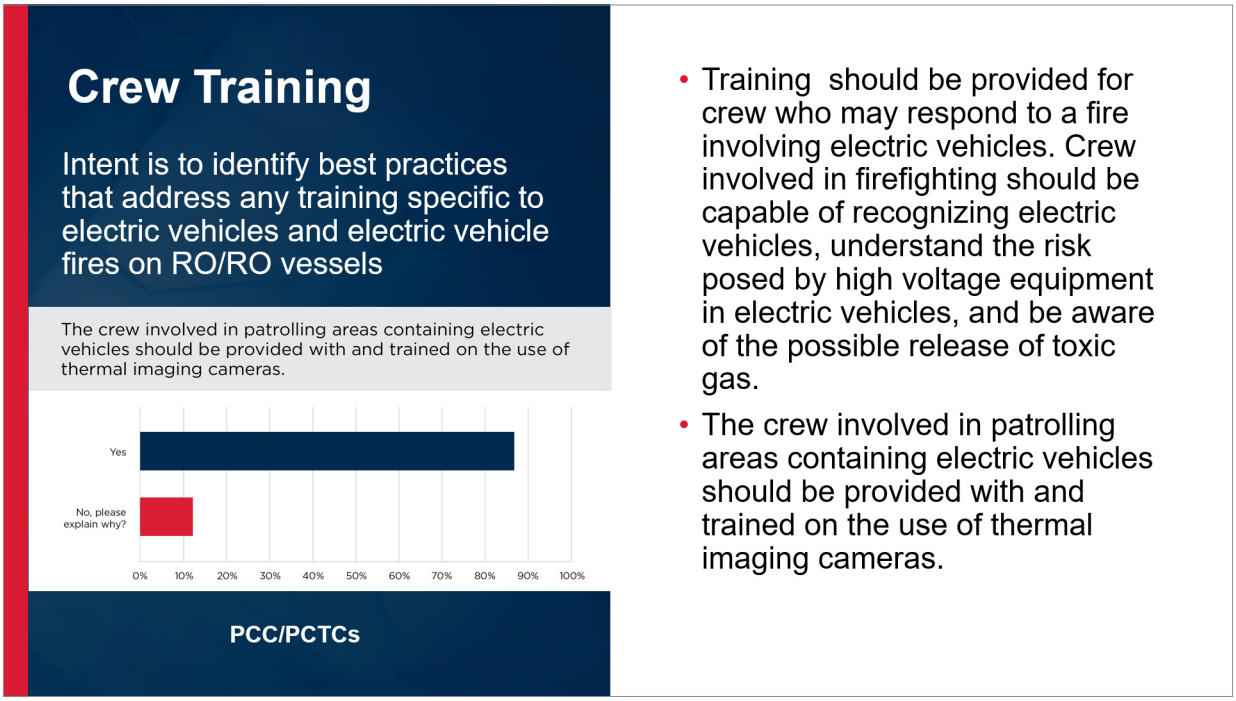

Figure 7: Crew Training Category – Workshop Display

- **Best Practice: Training should be provided for crew who may respond to a fire involving EVs. Crew involved in firefighting should be capable of recognizing EVs, understand the risk posed by high voltage equipment in EVs and be aware of the possible release of toxic gas.**

  One hundred percent of ferry and PCC/PCTC survey participants stated this was an appropriate best practice.

- **Best Practice: The crew involved in patrolling areas containing EVs should be provided with and trained on the use of thermal imaging cameras.**

  One hundred percent of ferry and 89 percent of PCC/PCTC survey participants indicate this was an appropriate best practice for each vessel type. The remaining survey responses stated that they did not believe thermal imaging cameras were effective.

3.3.6 FIREFIGHTING MEASURES

For the firefighting measures category, this item was presented to the group with the intent of identifying the best practices associated with firefighting tactics for EV carriage on ro/ro vessels. Figure 8 displays the survey results and best practices associated with this category.

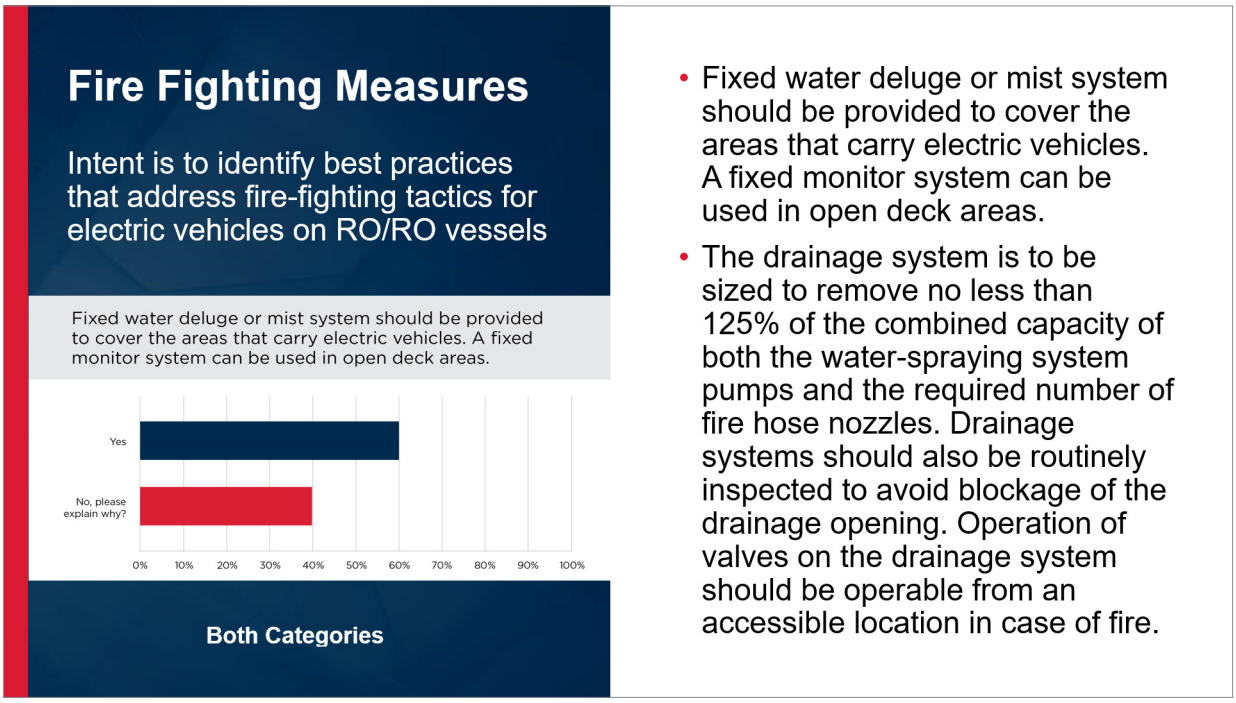

Figure 8: Firefighting Measures Category - Workshop Display

- **Best Practice: Fixed water deluge or mist system should be provided to cover the areas that carry EVs. A fixed monitor system can be used in open deck areas.**

  Sixty-seven percent of ferry and 53 percent of PCC/PCTC survey participants stated that this statement was an appropriate best practice. During the workshops, the topic was widely debated with the remaining survey participants stating that water spray was not an effective EV fire-suppression medium and that there was not enough deck space to implement such a system.

- **Best Practice: The drainage system is to be sized to remove no less than 125 percent of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles. Drainage systems should also be routinely inspected to avoid blockage of the drainage opening. Operation of valves on the drainage system should be operable from an accessible location in case of fire.**

  One hundred percent of ferry and 76 percent of PCC/PCTC survey participants stated this was an appropriate best practice. During the workshops, the topic was widely debated with the remaining survey participants stating that water spray was not an effective EV fire-suppression medium.

- **Best Practice: For EVs which are charged on board ferries, the ship's electrical supply to the vehicle should be cut prior to attempting to fight a fire, to reduce the potential of electric shock.**

  One hundred percent of ferry survey participants stated this was an appropriate best practice.

3.3.7 SPECIAL CONSIDERATIONS

The intent of this category was to address any special considerations involving EVs on ro/ro vessels that did not fall into any of the previously stated categories. Figure 9 displays the survey results and best practices associated with this category.

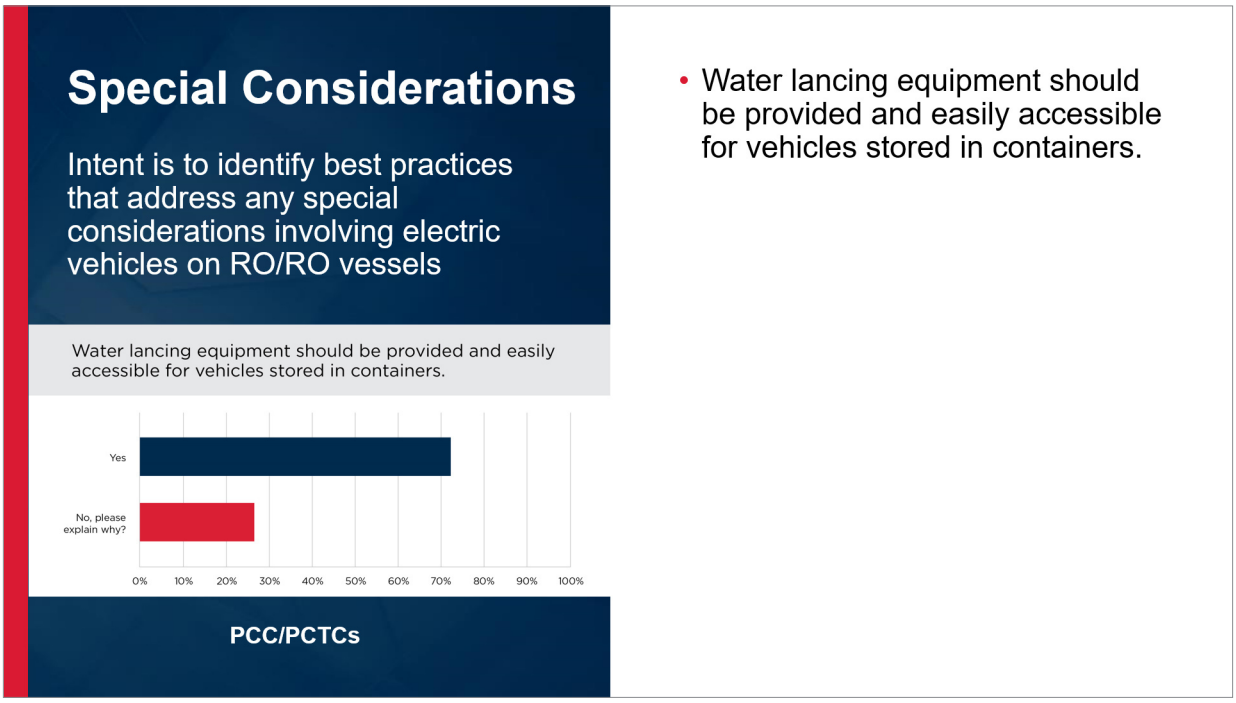

Figure 9: Special Considerations Category – Workshop Display

- **Best Practice: Water lancing equipment should be provided for all vessels carrying EVs and easily accessible for vehicles stored in containers.**

  One hundred percent of ferry and 76 percent of PCC/PCTC survey participants stated that this was an appropriate best practice. The remaining responses stated that lancing equipment could cause additional harm if the crew was not sufficiently trained in using them.

4 PUBLICATIONS

4.1 INTERNATIONAL STANDARDS

There are currently no published International Maritime Organization (IMO) standards specific to the transport of electric vehicles (EVs) on roll on/roll off (ro/ro) vessels. A proposed change to IMO Safety of Life at Sea (SOLAS) was made in January of 2020 in the subcommittee on ship systems and equipment. The draft amendment was circulated however no progress was made due to the pandemic which occurred during the second quarter of that year. An effort to reinstate this topic was introduced and presented in April 2022. LASHFIRE, an EU project, anticipated to be completed mid – 2023 is under progress aiming at developing proposals to IMO for effective fire protection on ro/ro ships. Other entities have similar efforts such as the U.K. Maritime and Coastguard Agency (MCA). MCA will publish a draft Marine Guidance Note MGN 653(M) – Electric Vehicles Onboard Passenger Ro-Ro Ferries in the summer of 2022.

4.2 ABS GUIDANCE AND OPTIONAL NOTATION

In the wake of recent incidents of fire on ro/ro vessels carrying vehicles, ABS has responded to industry concerns with an update to its Rules addressing EVs on board.

The culmination of more than a year of work with leading industry experts including ro/ro owners/operators, designers, regulators and other stakeholders, ABS has introduced new optional requirements within its Marine Vessel Rules and ABS Guide for Enhanced Fire Protection Arrangements. These requirements include supplemental fire detection, alarms and firefighting equipment as well as provisions associated with vehicle recharging.

ABS is the first classification organization to adapt its Rules to account for the specific challenges presented by increasing volumes of battery-operated vehicles transported by sea.

The new updated optional notation **EFP-C(EV)** builds on ABS' industry-leading experience in addressing firefighting and safety systems of cargo holds of container vessels. The updated optional notation requirements and Guides can be found on www.eagle.org.

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