List of Fire Safety Measures for the Maritime Transportation of Electric Vehicles

	Date	Revision history
Rev.00	2023.08	First issue
Rev.01	2023.1	Revised (1) part

Explanation of categories (ED, FS, FSP and FF)	
ED	Early Detection
FP	Fire Prevention
FSP	Fire Spread Prevention
FF	Fire-fighting

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ED		V: Sensors fitted to batteries send signals when abnormalities detected	Signals sent even when the vehicle's power is off. Signals can be montiored at control stations or other locations.	Receivers installed on each deck receive signals from vehicles and transfer said signals to manned areas via the ship's LAN. The locations of abnormal vehicles are then displayed on monitors located on the bridge.	・Effective regardless of lithium-ion battery location in vehicle. ・Makes early detection and isolation of abnormal batteries possible before they catch on fire. ・No need for fire patrols, thus smaller ship crews possible. ・Process is totally automated, so no chance for human error.	・There are currently no specifications for signals outputted by abnormal batteries. ・Cooperation from vehicle manufacturers is essential ・Cannot be applied to second-hand (i.e. used) vehicles.	
ED		S: Provide CCTVs in vehicle spaces	Confirm fire location and status using CCTVs*. *: The location and number of CCTVs installed depends on their installation purposes.	Case-1: Install CCTV for detecting vehicle fires Case-2: Install CCTV for monitoring fires in vehicle spaces	・Effective regardless of lithium-ion battery location in vehicle. ・Case 1: Makes remote detection of vehicles on fire possible (i.e. no need for crew members to enter fire affected areas). ・Case 2: Makes providing information about a fire's status, the fire-fighting situation, instructions for fire fighters, monitoring vehicle spaces after activating fixed fire-extinguishing systems, etc. possible. Moreover, the installation of CCTVs with zoom capabilities makes it possible to reduce the overall number of CCTVs installed.	・Many CCTVs may be needed in consideration of the clearances between vehicle roofs and ceiling beams. ・Privacy concerns for stevedores and other crew members. ・Difficult to simultaneously monitor many CCTV images. ・Possibility of foam coming into contact with CCTV lens or otherwise interfering with monitoring in cases where high-expansion foam fire-extinguishing systems are installed. ・Increased chances of CCTVs located near fires being damaged or otherwise affected.	
ED	FF	S: Use portable infrared thermography cameras during fire patrols	・Detect heat being generated by batteries located inside vehicles. Temperature of **℃ and above **: Limit temperature is the boiling temperatures of battery electrolytes.	Provide each fire patrol with one camera.	・Makes detection of flames possible even after fires have already broken out.	・It may be difficult to detect fires during fire patrols in cases where battery cells are located within protective housings or cases.	
ED	FS	S: Gas detectors (Target gases: HC gases)	Gas detectors for HC gases (methane, ethane, propane, etc.) are installed in vehicle spaces, ventilation ducts or both.	Install gas detectors which can detect PPM levels in vehicle spaces or ventilation ducts in consideration of the quantity of gas generated by abnormal batteries. Sound alarms in normally manned spaces when such gas is detected.	・Effective regardless of lithium-ion battery location in vehicle. ・Makes detection of abnormal batteries possible before vehicle fires break out.	・Many gas detectors are necessary when installing such systems in vehicle spaces ・Unable to precisely identify the locations of vehicles with abnormal batteries. ・Continuous ventilation is necessary when installing gas detectors in ventilation ducts, and this may possibly impair the functioning of smoke detectors. ・Less effective when fires break out relatively quickly after gas generation.	
ED		S: Gas detectors (Target gas: CO gas)	CO gas detectors are installed in vehicle spaces, ventilation ducts or both.	Install CO gas detectors in vehicle spaces, ventilation ducts or both. Sound alarms in normally spaces when such gas is detected.	・Effective regardless of lithium-ion battery location in vehicle. ・Makes early detection possible due to CO gas generated by batteries before they catch on fire.	・Unable to precisely identify the locations of vehicles with abnormal batteries. ・Less effective when fires break out relatively quickly after CO gas generation. ・CO gas detectors installed in ducts are not effective when there is no ventilation.	

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ED		S: Infrared gas detectors (Target gases: HC gases)	Infrared gas detectors consisting of infrared light emitting and receiving parts detect gases passing in between said parts. Gas concentrations can be measured because HC gases absorb infrared light.	<Windless conditions or no ventilation provided> The number specified below is necessary per deck for pure car carrier (PCC) cargo spaces which are 200 m x 38 m when the ranges of installed infrared gas detectors are 100 m. Ship-width direction:12 sets※ Ship-length direction:6 sets※ <Ventilation provided> Install detectors in ventilation ducts. ※Calculations based on the estimated range of methane gas within 100 ppm	・Infrared gas detectors installed in vehicle spaces make gas detection possible regardless of wind and ventilation conditions. ・Installation in ventilation ducts possible in cases where installation in vehicle spaces is impracticable. ・Makes warning crew members of risks of combustible gas being generated during thermal runaway possible before such gas ignites.	・Detection impossible in cases where infrared beams given of cannot be properly received. ・Careful consideration needs to be given to whether infrared beams can effectively pass through small gaps (e.g. 10 cm or less) between ceilings and the roofs/tops of vehicles. ・Risk of gas generated at other locations (e.g. decks located either directly above or below) passing through lashing holes (where provided) being detected and mistaken for gas generated on the monitored deck.	
ED		S: Portable gas detectors (Odor sensors)	Sensors which can detect the specific odors given off by battery electrolyte vapours or combustible gases.	Detect gas odors generated by abnormal batteries during fire patrols. Equip each fire-fighting team with one such detector.	・Makes detection of vehicle with abnormal batteries possible before fires break out.	・Unable to precisely identify the locations of vehicles with abnormal batteries. ・Risk of gas odors generated at other locations (e.g. decks located either directly above or below) passing through lashing holes (where provided) being detected and mistaken for gas odors generated on the monitor-ed deck. ・Requires odor levels under normal conditions be measured in advance to establish base levels.	
ED		S: Temperature measurement devices using fiber optic cables	Detect temperature increases of battery packs installed in the lower parts of electric vehicles through fibre optic cables run beneath such vehicles.	Detect increases in battery temperature and then sound alarms.	・Makes detection of temperature increases possible before fires break out.	・Risk of sensor cables being damaged during cargo loading and unloading operations. ・Temperature measurement device may not be possible to locate directly under the batteries of some vehicles, depending on the type of vehicle.	
ED		S: Smoke detection alarm systems	Provide addressable-type smoke detection systems and increase the number of such systems.	Increase the number of fire detectors installed beyond what is required by the FSS Code. Replace existing detectors with addressable type detectors (i.e. detectors capable of not only detecting but also of identifying location).	・Makes early detection of vehicles on fire possible. (Increases the possibility of detecting smoke from vehicle fires before it flows upward out of the deck through lashing holes (where provided) into upper decks. ・Makes the early commencement of fire-fighting operations possible due to the early detection of vehicles on fire.	・Increasing the number of systems installed means greater installation and maintenance costs, in terms of both time and money.	
ED		S: Smoke detection alarm systems	Increase the sensitivity of fire detectors by changing alarm set points (i.e. smoke density settings) to the lowest point possible to detect small amounts of smoke	Change minimum detectable smoke density from 8% as required by international conventions to 5% to increase possibility of detecting small amounts of smoke at the early stages of vehicle fires.	・Makes early detection of vehicles on fire possible due to increased sensitivity of smoke detectors.	・Increased sensitivity could possibly led to more false positives (i.e. misdetection)	

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ED		S: Heat detection alarm systems	Replace smoke detectors with heat detectors. ・Increase the sensitivity of heat detectors. ・Increase number of heat detectors (in addition to number required by international conventions).	Install heat detectors in ceilings of vehicle spaces which can detect heat generated by electric vehicle fires and then sound alarms.	・Makes identification of vehicles on fire possible through the detection of heat generated by such fires. ・Makes the early commencement of fire-fighting operations possible due to the early detection of vehicles on fire.	The number of heat detectors needed to comply with relevant international conventions and other regulations is going to be much greater than the number of smoke detectors needed to comply with the same conventions and regulations. Since SOLAS specifies the maximum effective detection range of heat detectors is 37 m2, which is half the maximum range specified for smoke detectors, twice as many heat detectors are going to be needed, and twice as many heat detectors means greater installation and maintenance costs, in terms of both time and money.	
ED		S: Flame detectors	Detection target: Flames of electric vehicle fires	Install sufficient number of flame detectors so as to cover all parts of vehicle spaces.	・Makes identification of vehicles on fire possible. ・Makes early commencement of fire-fighting operations possible due to the early detection of vehicles on fire.	・Similar to CCTVs, many flame detectors are needed when attached to the ceilings of vehicle cargo spaces due to the small gaps (i.e. 10 cm) between such ceilings and the tops or roofs of vehicles. ・The number of flame detectors installed, however, can be reduced by installing detectors in the floors of such spaces and targeting bottoms of vehicles.	
ED	FF	S: Fire detection loop systems and fire-fighting systems	Systems consist of fire-extinguishing media storage tanks (CO_2 gas, N_2 gas, etc.) connected by valves to tubes. The tubes are pressurised, and the heat from fires causes them to rupture, thus lowering their internal pressure and forcing the fire-extinguishing media out of the tank into the tubes and eventually into fire affected areas through the ruptured section of the tube. (No need for electrical power sources.) ・Storage tank valves has gauges that can sound alarms when low pressures are detected due to tube ruptures.	Run tubes connected via a valve to a storage tank containing fire-extinguishing media (CO_2 gas is recommended due to its fire-extinguishing and cooling effects) underneath the vehicles stored in vehicle spaces. When a vehicle fire breaks out, the heat from the fire will cause the section of the tube underneath said vehicle to rupture. This will cause the internal pressure of the tube to decrease and lead to the storage tank valve releasing the media in the tank being released into the tube. The media will pass through the tube to the ruptured section and then be released upwards towards the vehicle on fire. Sound alarms when pressures at storage tank valves have dropped.	・Makes identification of vehicles on fire possible. ・Makes early commencement of fire-fighting operations possible due to fire-extinguishing media being automatically released through ruptures in tubes caused by the heat generated by fires. ・Makes installation on existing ships possible due to no electrical power source being needed. ・Minimal effects on surrounding vehicles not on fire when CO_2 gas is used as fire-extinguishing medium.	・Risk of tubes installed on decks being damaged during cargo loading and unloading operations. ・Effectiveness of initial fire-fighting operations may be reduced in cases where tubes accidentally ruptured and fire-extinguishing media prematurely released. ・Removal and re-installation of tubes before and after cargo loading and unloading operations can take some time.	

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ED	FF	S: Fire detection loop systems and fire-fighting systems	System consists of tubes filled with fire-extinguishing media that pressurises the tube. The heat from fires causes hole in the tubes, thus releasing the fire-extinguishing media into fire-affected areas. (No need for electrical power sources)	Install tubes filled with fire-extinguishing media in ceiling beams (underneath deck transverses) above vehicle spaces. When a vehicle fire breaks out, the heat from the fire will cause the tube to rupture and the media contained therein to be released through the ruptured section downward onto the fire. Sensors which sound alarms upon the release of the media can optionally be fitted to the ends of such tubes.	・Makes early commencement of initial fire-fighting operations possible due to fire media being automatically released through ruptures in sensor tubes caused by the heat generated by fires. ・Makes identification of fire locations possible in cases where optional alarm functions are provided.	・Direction of fire-extinguishing media release cannot be controlled, and such media may be released from other sections of the tube melted by the heat from the fire or from coming into contact with sections of decks heated by fires.	
ED		S: Abnormal sound detection and alarm systems	Use AI to detect specific sounds (e.g. the whooshing or popping sounds of lithium-ion battery thermal runaway, electrolyte ejection sounds) and then sound alarms.	Install devices which can detect abnormal sounds in vehicle spaces, or use portable system which can detect abnormal sounds during fire patrols.	・Makes manpower savings possible due to application of AI. ・Makes early detection of abnormal sounds inaudible to crew members possible.	・Need to examine possibilities of detecting whooshing or popping sounds often generated during thermal runaway in advance. ・Need to examine possibilities of detecting electrolyte ejection sounds in advance.	
ED		S: Wireless temperature sensors	Install temperature sensors in vehicle battery packs prior to cargo loading and implement temperature monitoring using ship systems.	Connect general purpose temperature sensors (e.g. thermocouples, resistant temperature detectors) to wireless temperature sensors, and then monitor temperatures on laptops or panels by receiving data via wireless temperature sensor converters.	・Makes detection of vehicles with abnormal batteries possible. ・Makes identification of vehicles with abnormal batteries possible before fires break out.	・Many single receivers needed in additional to lap tops for monitoring and dedicated spaces for monitoring. ・Need to monitor temperature increases, except in cases where alarms can be set. ・Need to examine possibilities of detecting wireless signals correctly in advance. ・Need to install and remove sensors, which adds to the work done during cargo loading and unloading operations. However, sensors can be installed at the same time lashing belts are installed.	
ED		S: Image processing smoke detection systems	Detects smoke using image processing devices on images captured by CCTVs.	Install CCTVs to cover all parts of vehicle spaces and detect smoke using image processing devices. Components: One image processing device and two CCTV Sound visible and audible alarms when smoke detected.	・Makes smoke detection earlier than can be achieved using traditional smoke detectors possible. ・Makes continuous monitoring by crew members unnecessary due to use of image processing devices.	・Blurred or otherwise unclear images cannot be processed. ・Many image processing devices need to be installed. ・Not effective in unlit locations.	
ED		S: High sensitivity smoke detection systems (Sample extraction type)	Detects smoke densities between 0.001%/m and 20%/m, thus making it possible to detect even small amounts of smoke.	Install high sensitivity smoke detection systems in vehicle spaces or ventilation ducts. ※Estimated detection coverage area is 200 m2/ unit	・Makes early commencement of fire-fighting operations possible due to the ability to detect smaller quantities of smoke. ・Makes smoke earlier detection earlier than can be achieved using traditional smoke detectors possible because combustible gases and smoke can be detected at an earlier stage.	・Installation of sampling pipes required. ・Increased sensitivity could possibly lead to more false positives (i.e. misdetection).	
ED		S: Portable gas detection sensors (HC gases)	Used by fire patrols to detect HC gases generated by battery electrolytes.	Provide each fire-fighting team with one set of portable gas detection sensors to use during fire patrols.	・Makes detection of vehicles with abnormal batteries possible.	・Fires may have already broken out before combustible gases are generated. ・Unable to precisely identify the locations of vehicles with abnormal batteries.	

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FP		V: Electrical tripping by impact V: Monitoring battery condition by BMS	Ensure stevedores check battery conditions prior to turning off electric vehicles.	–	・Makes implementation of loading restrictions for vehicles with fire risks possible.	・May decrease cargo handling efficiency ・Stevedores and other relevant personnel need to be trained how to check for abnormal batteries.	
FP		S: Dilute combustible gases through ventilation	Operate ventilation systems, which, in principle, should be exhaust ventilation systems.	Plan ventilation system capacity so as to keep concentrations of combustible gases lower than 25%, which is the lower explosive limit.	・Makes prevention of the formation of explosive atmospheres possible due to continuous ventilation of space which helps prevent secondary fires. ・Makes cooling of batteries possible in the cases where air-cooling type ventilation is adopted, depending upon air flows and external temperatures.	・Risks of salt damage to cargoes. ・Risks of delayed smoke detector detection. ・Continuous ventilation may require installation of more generators in comparison to the number required for more traditional ventilation.	
FP		S: Explosion-protected electrical equipment (in cases where ventilation is not provided to prevent the forming of explosive atmospheres)	Install explosion-protected electrical equipment suitable for use in the presence of the combustible gases typically generated during thermal runaway. (Guideline)Specifications for explosion protection: Exd IIC **T2** or upward **and suitable for use in Zone 2** (Excludes ships complying with SOLAS II-2/20-1) **※FYI, refer to annex of "Summary table of Explosion protection grade for electric equipment inside the vehicle space".**	Install suitable explosion-protected electrical equipment in vehicle spaces. (Guideline)Exd IIC **T2** or upward **and suitable for use in Zone 2**	・Equipment is not a fire risk and can be used safely even when combustible gases generated by batteries form explosive atmospheres.	・Updating electrical equipment to explosion-protected types can increase costs. ・Suitable explosion-protected equipment might not exist.	(1)
FP		S: Install fire insulation at the boundaries of vehicle spaces	Delay fire spread to adjacent spaces by enhancing fire containment capability, thus providing more time for fire-fighting operations.	Install fire insulation at the boundaries of vehicle spaces.	・Makes prevention of heat transfer to adjacent spaces possible as long as the fire insulation installed is maintained in good condition. ・Makes prevention of fire spread to adjacent spaces possible in cases where fire insulation installed and boundaries separating spaces, thus allowing more time for fire-fighting operations. ・Makes fire containment possible.	・May significantly impact cargo loading and unloading operations. ・Unable to adopt such measures if the loading of EV is increased in future ・Heat insulation effectiveness is temporary and loses effectiveness over time. This needs to be considered since electric vehicle fires can burn for long periods of time.	
FP		S: Subdivision of fire protection compartments	Subdividing compartments to enhance the prevention of fire spread, and limit the areas requiring enhanced the fire-fighting measures.	Subdivide compartments covered by fixed fire-extinguishing systems.	・Makes prevention of fire spread possible as long as boundaries separating spaces can be quickly cooled after fires break out. ・Makes reduction of amount of fire-extinguishing media used by fixed fire-extinguishing systems possible.	・May significantly impact cargo loading and unloading operations. ・May increase overall weight of ship.	
FP		S: Utilisation of battery degradation assessment methods	・Create database for battery usage history. ・Adopt alternating current impedance method. ・Adopt discharge curve analysis method.	Assess whether electric vehicles are suitable for transporting as cargo by evaluating their batteries at ports prior to loading on board.	・Increases overall safety of transporting electric vehicles as cargo due to not loading high fire risk vehicles.	・Additional equipment needs to be provided at vehicle loading ports.	

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FSP		S:Isolate compartments using fixed water curtain systems	Install water curtain systems in vehicle spaces to help isolate vehicles on fire from other vehicles, thus aiding in the prevention of fire spread.	Install fixed water piping and nozzles for forming water film in vehicle spaces. Consider establishing system zones to isolate vehicles on fire from other vehicles, and install control panels for controlling of supply pumps, selection valves, etc.	・Makes highly effective prevention of fire spread possible. ・No significant impact on the number of vehicles that can be loaded because there is no need to physically isolate vehicles.	・May interfere with ventilation during fire-fighting operations. ・May be difficult to properly assess fire status when systems are in operation. ・Risk of exposure to saltwater which may effect cargo loading operations.	
FSP		S: Fire blankets	Use to smother fires (i.e. reduce their access to oxygen) and prevent their spread.	Provide fire blankets for covering vehicles with abnormal batteries and also for covering vehicles near vehicles on file.	・Makes shifting focus to other fire-fighting operations possible after blanket has been put in place. ・Makes prevention of fire spread to adjacent vehicles possible. ・Effective as initial fire-fighting measure.	・Putting blankets in place takes time. ・Risk of blankets damaging cargoes. ・Risk of disrupting other fire-fighting operations when blankets used to cover vehicles on fire.	
FSP		S: Prevent fire spread using water curtain hoses	Prevent fire spread using water curtain soaker hoses (i.e. hoses with small holes/pores along their length by design) connected to fire hydrants.	Connect water curtain hoses to fire hydrants and use to isolate fire affected areas.	・Makes additional fixed equipment unnecessary due to the use of ship hydrants ・Makes changing the areas isolated by water curtains possible.	・May be difficult to assess fire status when water curtain hoses are activated. ・May require installation of more fire pumps. ・Risk of interfering with ventilation during fire-fighting operations. ・May be difficult to pay out water curtain hoses depending on vehicle loading conditions.	
FF		S: Fire fighting using jets of water	Use cooling effects of water to extinguish electrical fires. Two jets of water from hoses and two jets of water from water mist applicators Fire nozzles (valves provided on nozzles for O/S changeover) Training for fire hose use(methods exist for quickly paying out fire hoses in narrow vehicle spaces)	Install water pumps capable of providing four jets of water. ・Two jets are to be used for cooling upper and lower decks. ・The remaining two jets are to be used via dual hose adapters fitted with four water mist applicator nozzles used to spray water mist onto the fronts, backs and sides of vehicles on fire.	・Makes implementation of water-based fire-fighting operations possible. ・Makes prevention of fire spread by cooling batteries and suppressing chemical reactions of batteries possible.	・Risks to crew members approaching vehicles on fire. ・Quick identification of vehicles on fire required.	
FF		S: Penetration nozzles	Use penetration nozzles to directly cools battery cells protected by hard shell coatings	Provide at least one penetration nozzle.	・Makes direct cooling of battery cells enclosed in steel casing possible.	・Risks of electric shock need to be considered. ・Risks to crew members approaching vehicles on fire. ・Identification of vehicles on fire required. ・Training in battery pack locations and penetration points for different kinds of batteries needed for crew members.	
FF		S: Increase number of fire fighter outfits and provide air compressors for recharging air cylinders	Provide necessary firefighter outfits and breathing apparatuses in consideration of the fire-fighting methods adopted and the long periods of time electric vehicle fires tend to burn.	Provide four fire fighter outfits in addition to two required by international conventions. Provide air compressors for recharging air cylinders. Provide manifolds for recharging multiple air cylinders simultaneously.	・Effective measure for dealing with electric vehicle fires which can burn for long periods of time.	・Empty air cylinders may need to be moved long distances to where air compressors are located in order to be recharged.	
FF		S: Provide portable infrared thermography cameras	Provide portable cameras with thermography capability for monitoring battery temperatures.	Provide at least one portable infrared thermography camera.	・Effective measure for confirming electric vehicle fires are completely extinguished or temperatures does not increase even after cooling operations are stopped.	・None	

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FF		S: Fixed fire-extinguishing systems (CO2 type)	The amount of CO2 gas in protected spaces is required to be sufficient to give a minimum volume of free gas equal to 45% of gross volume per the FSS Code. Maintains the inert gas atmosphere needed for fire-extinguishing operations for a period of time that exceeds the amount of time needed for a battery's chemical reaction to finish. Provide means for recharging CO2 gas tanks for subsequent fire-extinguishing operations into space.	Provide oxygen concentration meters in vehicle spaces. Consider releasing additional CO2 when oxygen concentrations are confirmed to be increasing. Increase the length of time an inert gas atmosphere can be maintained in vehicle spaces by improving airtightness of such spaces.	・Makes maintaining oxygen concentration levels possible because fires have not broken out. ・Makes complete battery burn out and the prevention of additional fires breaking out possible in cases where inert gas atmospheres can be maintained.	・Risks of entering vehicle spaces to crew increase once CO2 is released, thus making continuous fire-fighting operations impossible. ・Release of CO2 may initially impair monitoring of vehicle spaces by CCTV or other means, but visibility should improve after few minutes. ・Oxygen concentration levels may be difficult to maintain. ・Since chemical reactions can continue even in inert gas atmospheres, the heat from such reactions may effect adjacent vehicles. ・Combustible gases generated by batteries may continue to spread throughout vehicle spaces even after fires have been extinguished.	
FF		S:Fixed fire extinguishing systems (high-expansion foam type)	Five times the amount needed for the space with the greatest volume or for continuous foam release for 30 minutes (FSS Code requirement). Provide equipment for monitoring foam release conditions in vehicle spaces.	Study the proper timing of foam release because electricvehicle fires can burn for long periods of time and foam can be damaged and lose its effectives due to exposure to heat and impact from water or falling debris. Provide equipment to monitor foam and fire conditions in vehicle spaces.	・Make reapplication of foam possible because high-expansion foam fire-extinguishing systems are capable of releasing foam up to five times. ・Makes entry into spaces filled with foam by crew members possible.	・Risk of whiteout after foam has been applied, thus making assessing fire status difficult in cases where suitable monitoring equipment are not provided. ・Appropriate timing of foam reapplication needs to be decided.	
FF	FSP	S: Fixed fire-extinguishing systems (water-based type)	Water discharge density is to be comply with MSC.1/Circ.1430*. * MSC.1/Circ.1430 (Revised Guidelines for the Design and Approval of Fixed Water-Based Fire-Fighting Systems for Ro-Ro Spaces and Special Category Spaces)	Same as the column to the left.	・May be an effective measure in the prevention of fire spread to adjacent vehicles. ・Makes effective cooling of batteries possible in cases where water can be sprayed directly onto batteries. ・Makes reentry into spaces by crew members possible even in cases where such systems are still activated.	・May be difficult to spray water directly onto batteries located in the lower chassis of vehicles. ・Risk of seawater damage to cargoes. ・Risk of electrical fires, particularly with respect to 12 V batteries. ・Applying water to lithium-ion batteries may generate combustible gases (e.g. hydrogen gas) and toxic gases (e.g. HF gas)	
FF		S: Provide closed-circuit breathing apparatuses	Use breathing apparatuses which can supply air for long periods of time (several hours) because electric vehicle fires (battery fires) can burn for long periods of time.	Provide firefighters with closed-circuit breathing apparatuses.	・Makes continuous and prolonged fire-fighting operations for electric vehicle fires possible because there is no need to refill breathing apparatus air tanks.	・Spare air tanks for training purposes need to be provided because refilling high-pressure air tanks is not possible. ・Spares for chemical agents such as carlime need to be provided because such agent have expiration dates. ・Training on now to properly handle closed-circuit breathing apparatuses needed for crew members.	
FF		S: Personal alert safety systems (PASS)	Devices which aid in the speedy finding of injured fire fighters in fire affected spaces.	Equip devices in the space where fire-fighter outfits are located.	・Makes quickly locating injured or otherwise incapacitated crew members by rescue parties possible once fixed fire-extinguishing systems have stopped operating.	・None	

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FF		S: Ventilation control for fire-extinguishing operations	Ensure crew safety (e.g. ensure visibility, prevent asphyxiation) through ventilation control when fires break out. Can increase the amount of time which can be devoted to fire-fighting operations by creating an environment where fire fighting can be carried out without the use of breathing apparatuses. Can speed up the identification of vehicles on fire.	Provide vehicle spaces with an appropriate number of exhaust/supply type ventilation systems. Establish procedures for ventilation control based on fire location. Disperse smoke from vehicle spaces using auxiliary equipment such as positive pressure fans.	・Makes fire-extinguishing operations for long periods of time possible since no masks or breathing apparatuses are needed ・Make identification for fire sources easier because systems can clear smoke from fire affected areas, and, thus improve visibility.	・Smoke dispersion control plans need to be created for each deck because some locations with limited air circulation may exists.	
FF		S: Dedicated fire-extinguishing device for electric vehicle fires	Device cools batteries on fire by punching a hole in their bottoms and then filling them with water.	Provide at least one device for each vehicle spaces loaded with electric vehicles.	・Makes the cooling of batteries highly probably	・Distances between loaded vehicles may need to be adjusted depending upon the overall vehicle spaces size because the device needs to be placed underneath vehicles in order to be used. ・Height between deck and battery may need to be adjusted in some cases because the device needs to be placed underneath vehicles in order to be used.	
ED		S: Fixed infrared cameras	Detect increases in battery tempratures by monitoring the temperatures of ceilings of vehicle spaces. (Detect increases in ceiling temperatures which may result from vehicle fires breaking out on upper decks.)	Hang fixed infrared cameras facing upwards from the ceilings of vehicle spaces and use them to detect increases in the temperatures of batteries of cars loaded on upper decks by monitoring ceiling temperatures for corresponding increases. Sound alarms when such temperature increases are detected.	・Makes dection of abnormal batteries possible before fires break out	・Risk of fires becoming quite large and strong before any significant changes in deck temperature can be detected.	
ED		S: Photoelectric-isolation-type smoke detection devices	Smoke detectors using beams to detect electrolyte vapours eminating from the lower parts of vehicle chassis, thus making it possible to detect fires earlier than can be done with traditional fire detectors.	Study the number and arrangement of light sources and reveivers to determine what is appropriate for the ship.	・Makes early detection possible even under ventillation or no wind conditions.	・Risk of false positives due to the effects hogging and sagging may have on device accuracy.	

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	Date	Revision history
Rev.00	2023.08	First issue
Rev.01	2023.1	Revised (1) part

Explanation of categories (ED, FS, FSP and FF)	
ED	Early Detection
FP	Fire Prevention
FSP	Fire Spread Prevention
FF	Fire-fighting

Category (ED, FP, FSP and FF)	Safety measures V:Vehicle side S:Ship side	Specifications	Detailed specifications when applied to ships	Effectiveness and merits	Issues to consider	Revision

Appendix :Summary table of Explosion protection grade for electric equipment inside the vehicle space

Location (Distance from deck or platform)	Guideline for the safe transportation of Electric Vehicle				Rules for the survey and construction of steel ships(Chapter 20, Part R of the rule)			Loading dangerous goods inside car hold(Chapter 19, Part R of the rule)
	Hybrid Electric Vehicle(HEV)		Battery Electric Vehicle(BEV)		ICE Vehicle (Ch.20 part R of the rule)	Vehicle with compressed natural gas in ther fuel tank (Ch.20A part R of the rule)	Vehicle with compressed hydrogen in ther fuel tank (Ch.20A part R of the rule)	Dangerous goods (Ch.19 part R of the rule)
	Lithium ion battery in car	Other battery in car	Lithium ion battery in car	Other battery in car				
Not more than 450mm	Vapor group : ⅡC Temperature group : T3 and Suitable for use in the area of Zone1	TBD (It must be of ⅡAT3 or upwards which is required for ICE vehicle)	Vapor group : ⅡC Temperature group : T2 and Suitable for use in the area of Zone2	TBD	Vapor group : ⅡA Temperature group : T3 and Suitable for use in the area of Zone1	Vapor group : ⅡA Temperature group : T3 and Suitable for use in the area of Zone1	Vapor group : ⅡC Temperature group : T1 and Suitable for use in the area of Zone1	Vapor group : ⅡB Temperature group : T3 and Suitable for use in the area of Zone1 ＊: The above is minimum requirement.
More than 450mm	・6times/hr air change rate Vapor group : ⅡC Temperature group : T3 and Suitable for use in the area of Zone1 ・10times/hr air change rate and more Vapor group : ⅡC Temperature group : T3 and Suitable for use in the area of Zone2				・6times/hr air change rate Vapor group : ⅡA Temperature group : T3 and Suitable for use in the area of Zone1 ・10times/hr air change rate and more Protection degree : IP55 or Temperature group : T3 Suitable for use in the area of Zone2			