December 2024

ClassNK

Guidelines for the Safe Transportation of Electric Vehicles

(Edition 2.0)

[English]

Introduction

According to the International Energy Association (IEA), the number of registered electric vehicles (EVs) has been rapidly increasing worldwide in recent years (see Figure 1) and is only expected to continue increasing at such a pace for the near future (see Figure 2).

This, in turn, has led to calls by various interested parties for the establishment of regulations to ensure the safe maritime transportation of such vehicles. In April 2022, the Maritime Safety Committee (MSC) of the International Maritime Organization decided to discuss the development of appropriate and mandatory safety regulations for the transportation of such vehicle.

Although such regulations are, in principle, seen as being needed as soon as possible, the formal process of establishing new international regulations is generally time consuming and the IMO's MSC has stated that it hopes to complete this process sometime between 2024 to 2027.

Some national and regional governmental organizations, on the other hand, have taken the initiative and published their own guidelines related to the transportation of such vehicles ahead of the IMO; for example, the European Maritime Safety Agency (EMSA) published its *Guidance on the Carriage of AFVs in Ro-Ro Spaces* in May 2022 for alternative fueled vehicles (AFV) being transported in the ro-ro spaces of cargo and passenger ships, while the United Kingdom's Maritime and Coastguard Agency (MCA) published its Marine Guidance Note (MGN) 653 (M) in July 2022 for electric vehicles on board passenger roll-on/roll-off (ro-ro) ferries. These guidelines, however, are generally not unified in content and are not applied globally, and it is expected to still be a number of years before a common global guideline can be established and implemented.

Furthermore, in addition to safety regulations being developed at the national, regional and international levels, some vehicle carrier owners and management companies have been developing and implementing their own safety measures for the transportation of such vehicle.

In light of the above situation, ClassNK decided to independently publish its own *Guidelines for the Safe Transportation of Electric Vehicles* (hereinafter referred to as "Guidelines") in order to provide guidance to its clients regarding the characteristics of electric vehicle fires and the additional safety measures that can be implemented to help prevent such fires.

This Guidelines provides vehicle carrier owners and management companies with useful information and a framework regarding voluntary and advanced fire safety measures for the maritime transportation of electric vehicles.

The outline of technical service supplied by this society is specified in Chapter 1 to Chapter 3. As the services, this society may objectively evaluate advanced safety measures provided by the ship owners and management companies of vehicle carriers and affix the relevant class notations to vehicle carriers which are taken advanced fire safety measures in accordance with this guidelines.

The explanation for characteristics of electric vehicle fires is specified in Chapter 5, with aim of sharing necessary knowledge for establishing fire measures. Furthermore, the explanation of the guidelines for such fires including example measures are specified in Chapter 6 based on the characteristics of electric vehicle fires specified in Chapter 5.

As a companion to the Guidelines, ClassNK has also made available a "List of Fire Safety Measures for the Maritime Transportation of Electric Vehicles" on its official website. This list provides further examples of prevention measures studied by ClassNK related to electric vehicle fires (including the various pros, cons and implementation challenges of said measures), and is intended to be useful reference for those interested in implementing such fire measures.

It is the hope of ClassNK that this Guidelines and the list for fire measures will not only make a positive contribution to the safe maritime transportation of electric vehicles, but will also be a source of inspiration for developing new technologies related to the transportation of such vehicles.

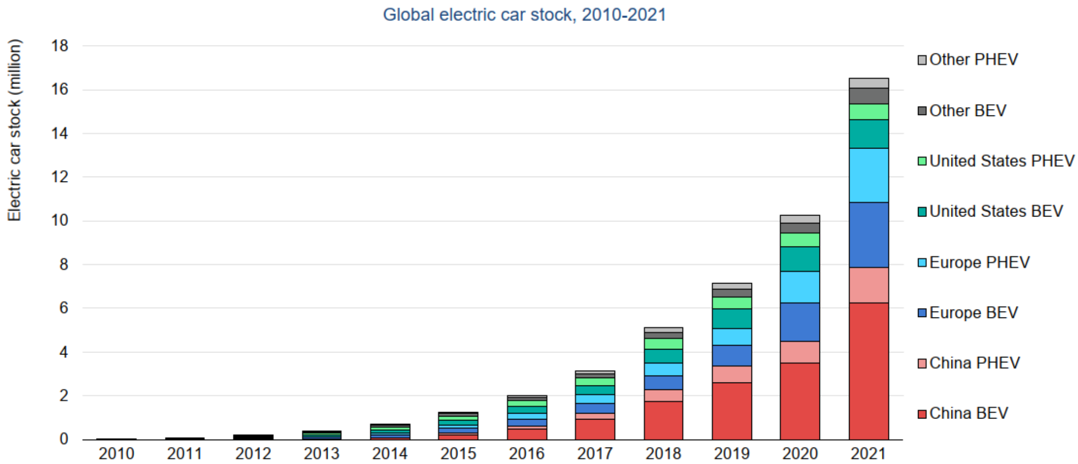


Figure 1 Number of registered electric vehicles (as of December 2021)
(Source: IEA Global EV Outlook 2022)

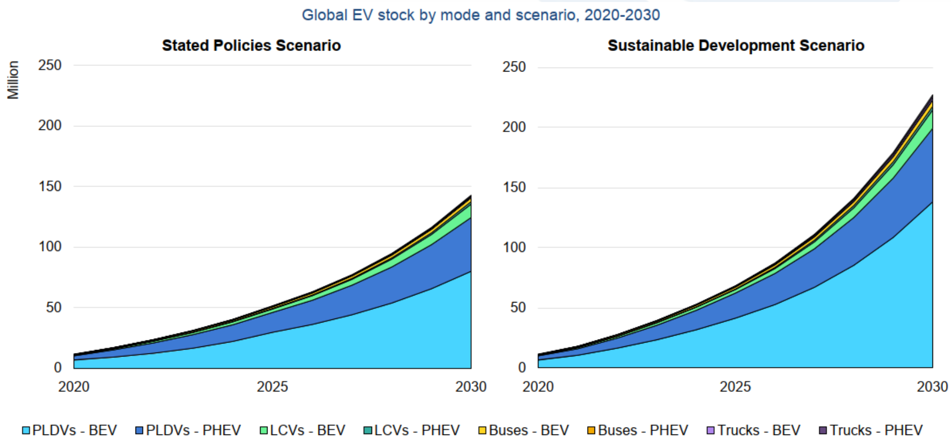


Figure 2 Expected future number of registered electric vehicles by 2030.
(Source: IEA Global EV Outlook 2022)

Revision History

No.	Date	Category	Details
1	August 2023	New	First Issue
2	December 2024	Revision	Adding countermeasur for Escaping

Guidelines for the Safe Transportation of Electric Vehicles

CONTENTS

Chapter 1 GENERAL PROVISIONS

1.1 Application

This *Guidelines for the Safe Transportation of Electric Vehicles* (hereinafter referred to as "Guidelines") applies to ships classed with the Nippon Kaiji Kyokai (hereinafter referred to as "the Society") that are provided with additional fire-fighting measures for the transportation of electric vehicles and for which applications for the affixation of corresponding class notation to their classification characters are submitted.

1.2 Affixation of Class Notation

1 The notation ***A****dditional* ***F****ire-fighting Measures for* ***V****ehicle* ***C****arriers (XX)(EV)* (abbreviated as *AFV(XX)*) is to be affixed to the classification characters of ships provided with relevant additional fire-fighting measures in accordance with this Guidelines. The additional fire-fighting measures provided are described by the notation *XX*.

(For example, the notation ***A****dditional* ***F****ire-fighting Measures for* ***V****ehicle* ***C****arriers (****F****ire* ***D****etection)(EV)* (abbreviated as *AFVC(FD)(EV)*) is to be affixed to the classification characters of ships provided with the additional fire-fighting measures specified in **5.2.2**)

2 In cases where a ship is provided with certain additional fire-fighting measures, said additional fire-fighting measures are (as specified in **-1** above) described using the notation *XX*.

(For example, the notation *AFVC(FD, PS)* is to be affixed to the classification characters of ships provided with the additional fire-fighting measures specified in **5.2.2** and **5.2.3**.)

1.3 Termination of Class Notation

The Society will delete relevant class notation in cases where additional fire-fighting measures approved in accordance with this Guidelines are not properly maintained. Compliance with this Guidelines, however, is optional and not a condition of class maintenance.

1.4 Class Notation

Table 1.1 shows a list of relevant class notation. This notation can be affixed to the classification characters of ships provided with relevant additional fire-fighting measures in accordance with this Guidelines.

Table 1.1 Affixation of Class Notation – Vehicle Carriers

Class notation	Section	Class Notation	Note
AFVC (FD)(EV)	**5.2.2**	**Additional Fire-fighting Measures for Vehicle Carriers (Fire Detection)(EV)**	For example, ***AFVC(FD, PS) (EV)*** is affixed to the classification characters of ships complying with **5.2.2** and **5.2.3**.
AFVC (PS)(EV)	**5.2.3**	**Additional Fire-fighting Measures for Vehicle Carriers (Prevention of Secondary Fire)(EV)**	
AFVC (PFS)(EV)	**5.2.4**	**Additional Fire-fighting Measures for Vehicle Carriers (Prevention of Fire Spread)(EV)**	
AFVC (FF)(EV)	**5.2.5** **5.2.6** **5.2.7** **5.2.8** **5.2.11**	**Additional Fire-fighting Measures for Vehicle Carriers (Fire-fighting)(EV)**	
AFVC (EFF)(EV)	**5.2.9**	**Additional Fire-fighting Measures for Vehicle Carriers (Enhanced Fixed Fire-extinguishing System)(EV)**	
AMEVC(EV)	**5.2.12**	**Additional Measure for Escaping from Vehicle Carrier(EV)**	

Chapter 2 SUBMISSION OF PLANS AND DOCUMENTS

2.1 Submission of Plans and Documents

1 For ships intending to undergo Initial Surveys, the plans and documents specified in **Table 2.1** are to be submitted to the Society in addition other plans and documents required by the Society's Rules for the Survey and Construction of Steel Ships. Notwithstanding this requirement, it is not necessary to submit a separate set of such documents for Initial Surveys carried out at Classification Surveys During Construction.

2 Submission of additional plans and documents may be required when deemed necessary by the Society.

3 The test plan for each additional measure is to be submitted during the Initial Survey specified in **3.2**.

Table 2.1 Submission of Plans and Documents – Vehicle Carriers

Section	Class notation	Plans and Documents
5.2.2	***AFVC (FD)(EV)***	(1) Countermeasures for electric vehicle fires (documents specifying the concepts for improving fire detection capability) (2) Documents showing the fire detection capability improvement effects of **(1)** above, relevant calculation sheets, simulation results, etc. (3) Plans for relevant systems (including certificates showing system compliance with recognized standards) (4) Other documents deemed necessary by the Society
5.2.3	***AFVC (PS)(EV)***	(1) Countermeasures for electric vehicle fires (documents specifying the concepts for preventing secondary fires) (2) Documents showing the fire prevention effects of **(1)** above, relevant calculation sheets, simulation results, etc. (3) Plans for relevant systems (including certificates showing system compliance with recognized standards) (4) Other documents deemed necessary by the Society
5.2.4	***AFVC (PFS)(EV)***	(1) Countermeasures for electric vehicle fires (documents specifying the concepts for preventing fire spread) (2) Documents showing the fire spread prevention effects of **(1)** above, relevant calculation sheets, simulation results, etc. (3) Plans for relevant systems (including certificates showing system compliance with recognized standards) (4) Other documents deemed necessary by the Society
5.2.5 **5.2.6** **5.2.7** **5.2.8** **5.2.11**	***AFVC (FF)(EV)***	(1) Countermeasures for electric vehicle fires (documents specifying the concepts for fire-fighting operations) (2) Documents showing the fire-fighting effects of **(1)** above, relevant calculation sheets, simulation results, etc. (3) Plans for relevant systems (including certificates showing system compliance with recognized standards) (4) Other documents deemed necessary by the Society
5.2.9	***AFVC (EFF)(EV)***	(1) Documents and specifications for fixed fire-extinguishing systems (2) Results of factor analysis of operation reliability for fixed fire-extinguishing system and risk analysis (3) Countermeasures for operation reliability of fixed fire-extinguishing systems (4) Other documents deemed necessary by the Society
5.2.12	***AMEVC(EV)***	(1) Concept and specification for Safety escaping from Vehicle carrier (2) Result of factor analysis of safety escaping from Vehicle carrier in case of fire in cargo hold (3) Document or specification of equipment for escaping (4) Other documents deemed necessary by the Society

Chapter 3 SURVEYS

3.1 General

3.1.1 Kinds of Surveys

The kinds of surveys covered by this Guidelines are as follows.
(1) Initial Surveys
(2) Periodical Surveys
(3) Occasional Surveys

3.1.2 Timing of Surveys

The timing of surveys specified in **3.1.1** is as follows.
(1) Initial Surveys are to be carried out at the time the application for the survey is made.
(2) Periodical Surveys are to be carried out at the times of Annual Surveys, Intermediate Surveys and Special Surveys for ship classification purposes (i.e. the surveys required by **1.1.3-1(1)** to **(3)**, **Part B of the Rules for the Survey and Construction of Steel Ships**).
(3) Occasional Surveys are to be carried out on the following occasions at times other than Initial Surveys or Periodical Surveys.
  (a) In cases where additional fire-fighting or other related measures of ships are changed or replaced.
  (b) In cases where any conversions affecting the additional fire-fighting or other related measures referred to in **(a)** above of ships are carried out.
  (c) In cases where any applications for surveys are submitted by ship owners.
  (d) Other occasions where Occasional Surveys are considered to be necessary.

3.1.3 Periodical Surveys Carried Out in Advance and Postponement

The requirements for Periodical Surveys carried out in advance are to be in accordance with requirements relevant to Periodical Surveys for ship classification purposes (i.e. the surveys required by **1.1.4** or **1.1.5, Part B of the Rules for the Survey and Construction of Steel Ships**).

3.1.4 Ships Laid-up

Ships laid-up are not subject to the Periodical Surveys specified in **3.1.1(2)**.

3.1.5 Preparation for Surveys and Other Related Issues

1 In cases where ships are to be surveyed in accordance with this Guidelines, it is the responsibility of shipowners to notify surveyors of the locations where they wish to undergo such surveys. Surveyors are to be advised of surveys a reasonable time in advance so that such surveys can be properly carried out.

2 All preparations required for registration, periodical and other surveys specified in this Guidelines as well as those which may be required by surveyors in accordance with this Guidelines are the responsibility of shipowners or their representatives.

3 Applicants for surveys are to arrange supervisors who are well conversant with all of the survey items required for the preparation of such surveys and who are able to provide all necessary assistance to surveyors according to their requests during such surveys.

4 Surveys may be suspended in cases where necessary preparations have not been made, any appropriate supervisor is not present, or surveyors considers the safety needed for the proper execution of the survey is not ensured.

5 In cases where repairs are considered to be necessary as a result of surveys, surveyors will notify survey applicants of their findings. Upon receiving such notification, applicants are to obtain surveyor verification after carrying out any necessary repairs.

3.2 Initial Surveys

3.2.1 General

During Initial Surveys, relevant measures, systems, etc. are to be examined and surveyed in order to ascertain whether this Guidelines is satisfied.

3.2.2 Survey Items

The following items are to be confirmed during Initial Surveys.

(1) The appropriate installation of relevant fire-fighting measures.

(2) The proper operation of said relevant fire-fighting measures.

(3) The proper provision on board of all relevant documents, procedures manuals and record books.

(4) The proper maintenance on board of all relevant equipment, documents, procedures manuals, and record books, etc. in cases where Initial Surveys are carried out at times other than at Classification Surveys during Construction, and the proper keeping of records required for record books.

3.3 Periodical Surveys

3.3.1 General

Relevant fire detection and fire-fighting measures are to be confirmed during Periodical Surveys in order to ascertain whether the requirements of this Guidelines are satisfied.

3.3.2 Survey Items

The following items are to be confirmed during Periodical Surveys.

(1) The proper maintenance of relevant fire-fighting measures.

(2) The proper onboard maintenance of all relevant documents and procedures.

(3) The proper keeping of relevant records and recording of necessary information.

3.4 Occasional Surveys

3.4.1 General

In cases where relevant fire-fighting measures are changed or replaced, Occasional Surveys are to be carried out and such measures are to be confirmed as complying with this Guidelines.

Chapter 4 CHARACTERISTICS OF ELECTRIC VEHICLE FIRES

4.1 General

4.1.1 Purpose

This chapter specifies those matters to be considered with respect to the safe transportation of electric vehicles.

4.1.2 Terminology

The terminology used in this Guidelines is as follows.

Terminology	Meaning
Electric vehicle	Vehicles powered by motors whose source of energy is electricity. This includes not only Battery Electric Vehicles (BEV) (i.e. vehicles powered solely by rechargeable batteries), but also Hybrid Electric Vehicles (HEV) and Plug-in Hybrid Electric Vehicles (PHEV) (i.e. vehicles powered by a combination of rechargeable batteries and gasoline). It does not, however, include Fuel Cell Vehicles (FCV) (i.e. vehicles powered by fuel cells and motors) and FCV are, therefore, not covered by this Guidelines.
Rechargeable battery	Batteries that can be discharged and then re-charged for further use.
Battery cell	Battery cells are the most basic components of rechargeable batteries, and are capable of storing electricity. Such cells consist of positive electrodes, negative electrodes, electrolytes, separator exterior materials and PTC elements.
Battery module	A package combining several battery cells.
Battery pack	A battery combining several battery modules.
Electrolyte	A solution with electrical conductivity properties created by dissolving ionic substances in polar solvents such as water.
Thermal runaway	The situation in which temperature cannot be controlled due to repeated heat generation by chemical reactions. The repeated heat generation by chemical reactions is generated by internal short circuits in battery cells.
Immediate danger to life or health	The upper concentration limit of a chemical substance representing the threshold level for avoiding situations in which escape within 30 minutes is impossible and adverse effects on health become permanent.
Fire-fighting / Flame suppression	Stopping combustion / Extinguishing visible fires
Fire suppression	Stopping combustion with no need for further fire fire-fighting operations.
Burning out	The situation in which combustible material completely burns out. In this Guidelines, the situations in which electrolytes evaporate completely and no further chemical reactions generating heat occur.
Flashover	The phenomenon in which a space is filled with combustible gases generated by the thermal decomposition of combustible materials due to internal fires or in which combustible materials used in ceiling interiors rapidly ignite due to thermal decomposition of radiant heat.
Backdraft	The phenomenon in which a fire spreads quickly when fresh air is inadvertently introduced into an incompletely burning compartment due to a lack of oxygen.
Overhaul	The searching and extinguishing of hidden and remaining fires after main fire-fighting operations have ceased.

4.2 Characteristics of Electric Vehicles

4.2.1 Electric Vehicles

Electric vehicles are vehicle powered by supplying electricity stored in rechargeable batteries to motors. In general, lithium-ion batteries are used as rechargeable batteries.

4.2.2 Electric Vehicle Batteries (EVB)

Lithium-ion batteries are commonly used as rechargeable electric vehicle batteries (EVB) because their volumetric energy densities and gravimetric energy densities are higher than other kinds of rechargeable batteries, and they suffer lower degrees of degradation due to their low memory effects and low self-discharge rates. The positive electrode uses cobalt (NMC), iron phosphates (LFP), etc., whereas the negative electrode uses carbon-based metals with electrolytes used as the organic solvent. In general, lithium-ion battery packs for electric vehicles are installed on the lower parts of vehicle bodies. Such battery packs incorporate some battery modules, and these battery modules incorporate some laminated type, prismatic type or cylindrical type battery cells.

4.2.3 Safety

Electric vehicles installed with high-voltage EVB are typically provided with the following **(1)** and **(2)** safety measures.

(1) Measures against electric shock
High-voltage EVB and other high-voltage parts are usually located at positions to avoid their coming into contact with the occupants of such vehicles during collisions. In addition, such EVB and parts are protected by robust enclosures and a system for isolating the high-voltage circuits is provided by collision detection systems.

(2) Prevention of thermal runaway and external propagation
Battery management systems monitor and control current, voltage and temperature to prevent thermal runaway. A safety function is provided to shut down high-voltage circuits when abnormalities are detected.

4.2.4 Characteristics of Electric Vehicle Fires

It is said that gasoline-powered vehicle fires are often caused by short circuits in electrical systems or by other heat sources igniting combustible material in either the vehicle's engine compartment or in its interior. Such fires usually start small, generating white smoke, and gradually spread until they reach external components. Eventually, the fire's heat causes the vehicle's windows to break, and the influx of oxygen causes the fire to then spread throughout the rest of the vehicle. This progression of fire is the same with respect to electric vehicle fires.

The main consideration when it comes to electric vehicle fires is the installation of large capacity rechargeable EVBs. It can be quite difficult to prevent the internal short circuits generated by manufacturing defects that lead to thermal runaway even in cases where battery management systems are functioning correctly, but such systems may be inactive during the transportation of the vehicle and this possibility needs to be considered. Moreover, even though in some cases the fire source may be the EVB itself, it should be noted that fires can be generated by other sources and then just eventually spread to the EVB. For this reason, it is important to confirm the actual source of the fire.

Rechargeable batteries are devices that convert chemical energy to electrical energy. An exothermic chemical reaction which does not require oxygen can be caused by heat generated by an internal short circuit or a fire, and this reaction can lead to the melting of lithium-ion battery separators, which then can lead to further short circuits and eventually thermal runaway. In addition, combustible gas may be generated, and may even ignite if exposed to an ignition source. The heat generated by the ignition of such gases may eventually cause the vehicle's body to catch fire. Finally, there is also a possibility of toxic gas generation, which may pose additional risks to the health of the crew of ships transporting such vehicles.

With all of the above in mind, special attention needs to be given to the following **(1)** to **(3)**.

(1) Vehicle body

Since electric vehicles chassis are generally designed to be as light as possible in consideration of the additions to overall vehicle weight resulting from the number of EVBs being provided to increase battery capacity, lighter materials (e.g. composite resin) are more frequently used for such chassis than is typically the case with respect to traditional gasoline-powered vehicle chassis. These lighter materials tend to be more combustible than perhaps more traditional materials (e.g. steel) and the risk of their being ignited needs to also be considered in addition to the risks of combustible gas generated by the EVBs being ignited.

(2) EVB thermal runaway

Thermal runaway is a real possibility even without the EVB being exposed to external heat sources like fires. In some cases, thermal runaway may result from exothermic chemical reactions caused by external impact or internal short circuits caused by foreign objects contaminating battery cells. As these exothermic chemical reactions progress, thermal runaways in which EVB temperatures eventually exceed 1000℃ may be caused. In other cases, thermal runaway may result from heat generated by external sources. EVBs affected by thermal runaway may continue to heat up until potential differences between electrodes are eliminated and the chemical reaction just stops. Such EVBs, however, may emit combustible gases before the chemical reaction stops, and these gases may impede fire-fighting operations. In addition, there exists the possibility of a fires re-igniting after the fire-fighting operations have stopped. Therefore, it should be noted that fire-extinguishing operations may take quite a long time to complete. Furthermore, consideration also needs to be given to the fact that EVB are being developed to achieve higher energy density through improvement of active materials and electrolytes so as to achieve greater and greater driving ranges. Since such high-density/large-capacity EVB are capable of storing large amounts of energy, they are also capable of generating greater amounts of heat when defective or otherwise used under unsafe conditions and can create new hazards that need to be considered.

(3) Combustible and toxic gases

Although the electrolytes inside EVBs contain various substances, they are primarily composed of carbonate ester. The heat generated by thermal runaway causes EVB electrolytes to boil and be changed into white gases with combustible characteristics that are then emitted. EVBs will catch fire when the temperatures of said white gases reach their ignition points or when the white smoke generated comes into contact with an ignition source. The chemical reactions occurring during thermal runaway generate combustible gases (such as hydrogen, methane, etc.) toxic gases (such as hydrogen fluoride (HF)) and oxygen from positive electrodes. Hydrogen fluoride, in particular, is extremely toxic and poses immediate danger to human life or health at values of 30 *ppm*.

4.2.5 Electric Shock

Electric vehicle fires are generally considered to be a type of electric fire because the voltage of EVBs can typically be quite high, ranging from 300 *V* to 400 *V*. Since electricity easily flows in the direction of low resistance (e.g. parts experiencing internal short circuits), the risk of electric shock during fire-fighting operations is believed to be low when spraying water on EVBs experiencing internal short circuits. It can, however, be very difficult to judge whether all battery cells have experienced internal short circuits during electric vehicle fires because the number of battery cells making up a single EVB can be up to several hundred. Therefore, the risk of electric shock due to possibly spraying water on healthy battery cells needs to be considered.

Chapter 5 Additional Fire Safety Measures

5.1 General

1 This chapter provides general information regarding equipment that may assist in responding to electric vehicle fire and methods for properly using such equipment. It is important to sufficiently understand the constraints and precautions related to the on-board use of such equipment, and to also adopt supplemental measures for such constraints and precautions as needed.

2 For ships applying for the affixation of the notation specified in this Guidelines, the fire safety measures specified in this chapter are required in addition to compliance with **Part R of the Rules for the Survey and Construction of Steel Ships**.

3 Measures specified in this chapter are to satisfy relevant **Rules for the Survey and Construction of Steel Ships**, where applicable. Other measures are to be as deemed appropriate by the Society.

(Note) The Society has compiled the results of its examination into the effectiveness, benefits, concerns, items to be considered, etc. of such equipment and its use in responding to electric vehicle fires as the "List of Fire Safety Measures for the Maritime Transportation of Electric Vehicles". This list is available of the Society's official website (HOME > Products & Services > Safety Measures for Maritime Transportation of Electric Vehicles).
Since the Society only carried out a limited examination of such equipment, there may be similar products by other manufacturers not included in the list which have different features and performance characteristics. The information contained in the list is, therefore, intended for reference purposes only and is not intended to be a comprehensive guide to such equipment.

5.2 Responding to Electric Vehicle Fires

5.2.1 General

It can be difficult to judge which kind of vehicle fire has occurred on ships transporting both gasoline-powered vehicles and electric vehicles. For such ships, therefore, the methods for responding to vehicle fires may need to be adjusted accordingly due to differences in the characteristics of gasoline-powered vehicle fires and electric vehicle fires. This means it is essential to detect such fires as early as possible accurately assess their origin so that appropriate fire-fighting operations can be carried out.

5.2.2 Early Detection

1 It may take a long time to extinguish EVB fires in general, but the response to such fires may even prove to be further difficult in the case of thermal runaway due to chemical reactions continuously occurring. It is, therefore, necessary to isolate EVBs of electric vehicles are showing signs of abnormalities from other vehicles prior to any fires breaking out and commence fire-fighting operations at the early stages of any fires that might occur. It is important to detect any signs of thermal runaway as early as possible so that responsible crew members can be notified of the potential danger and can make preparations to commence fire-fighting operations at the early stages of any fires that might occur.

2 EVBs do not generally catch on fire suddenly without warning; rather, the build up to thermal runaway tends to occur over a period of time with various signs (excessive heat, generation of combustible or toxic gases, etc.) indicating the presence of abnormal conditions being given off prior to the EVB igniting. A conceptual diagram of each exothermic chemical reaction generating heat and leading to thermal runaway is shown in **Figure 5.1**, whereas the temperature changes and reaction times leading to thermal runaway for a typical 18650 type lithium-ion EVB are shown in **Figure 5.2**.

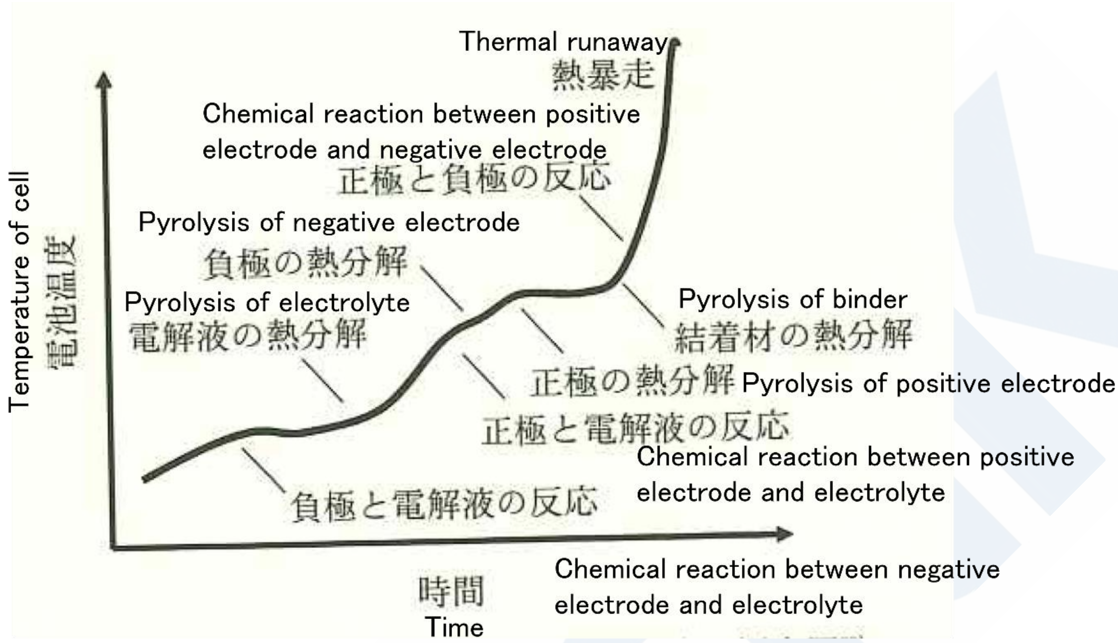


Figure 5.1 Heat reaction leading to thermal runaway
(Source: Japan Association for Fire Science and Engineering, *Handbook for Fire Science and Engineering*, 4th edition, p. 647, translated by ClassNK)

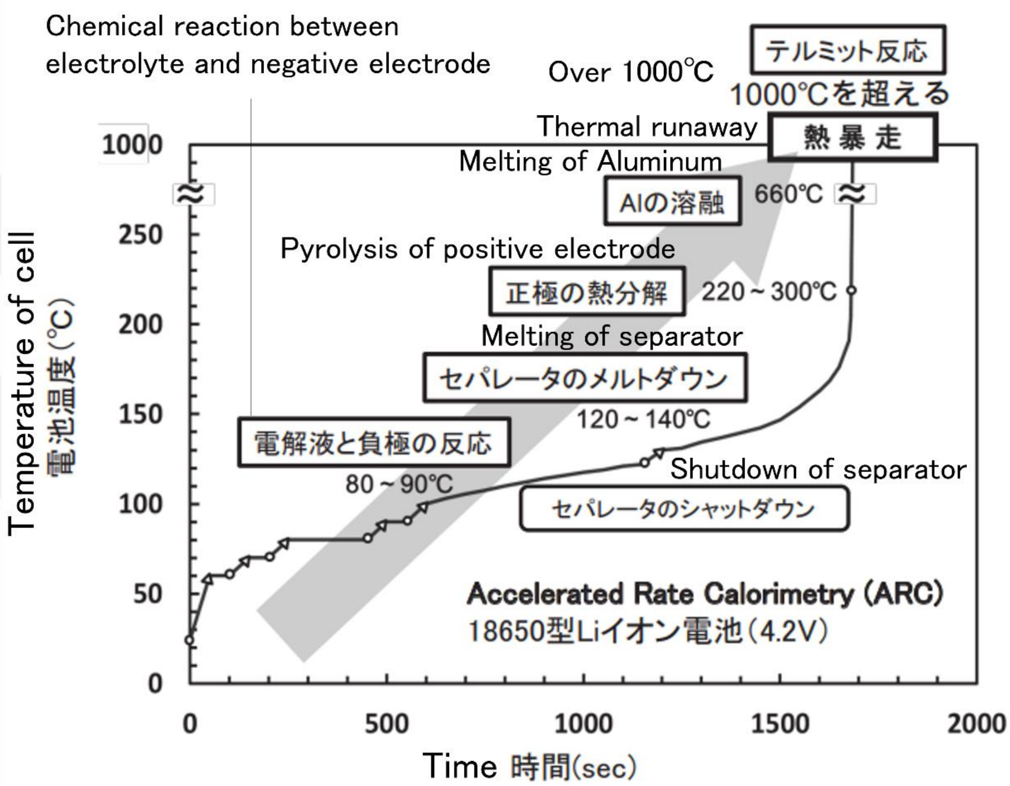


Figure 5.2 Sample temperatures and times leading to thermal runaway
(Source: The Surface Finishing Society of Japan, *Surface Technology* Vol. 70, No. 6, pp. 301–307, Small Feature

Articles: "Reliability assessment test for quality and safety of product" and "Thermal Runaway Mechanism and High Safety Technology of Lithium Ion Battery", translated by ClassNK)

3 It is possible to identify abnormal EVBs by monitoring for combustible gases and toxic gases in vehicle spaces since such gases are often generated by such EVBs prior to their catching on fire. The detection of such gases makes it possible to commence fire-fighting operations at the early stages of a fire. This is important to commence full fire-fighting operations at the early stages of a fire, the difficult it becomes completely extinguish a fire by initial fire-fighting operations such as using portable fire extinguishers.

4 Since vehicles being transported as cargo tend to be tightly loaded into vehicle spaces, it may take a considerable amount of time identifying which vehicle is on fire using only smoke detectors. Since the early identification of a vehicle on fire makes it possible to take appropriate measures to prevent fire spread, it is important to implement measures such as the following **(1)** to **(4)**.

(1) Gas detection systems
Gases generated from lithium-ion EVBs are generally hydrogen carbon gases (such as methane, ethane, propane), hydrogen gas and carbon monoxide. Therefore, a method that gas detection systems for such gases are installed in vehicle spaces, ventilation ducts, etc. may be considered.

(2) Smoke detectors
Smoke detectors sound alarms when smokes reach their sensors. However, it may take some time for alarms to be sounded when smoke flow is prevented from easily reaching detectors due to obstructions such as beams and girders on the deck or smoke flowing upwards to upper decks via lashing holes. Therefore, consideration needs to be given to smoke flow characteristics and vessel structure when arranging smoke detectors to ensure they detect smoke as quickly and effectively as possible.

(3) Heat detectors and flame detectors
Heat detectors sound alarms when the heat of fires reach their sensors and flame detectors sound alarms when infrared radiation of fires reach their sensors. Since such detectors are only activated by the presence of flames, they make it possible to quickly identify the location of vehicles on fire and, thus, commence full fire-fighting operations at a fire's early stages.

(4) CCTV (Surveillance Cameras)
Closed-circuit television (CCTV) cameras within vehicle cargo spaces make it possible to monitor white smoke indicating combustible gases being generated by abnormal lithium-ion EVBs and for black smoke indicating a vehicle fire. This can shorten the time needed to identify vehicles with abnormal EVBs and vehicles on fire and allow full fire-fighting operations to commence at a fire's early stage.

5.2.3 Prevention of Secondary Fires

Vehicle fires may lead to secondary fires in other areas of vehicle spaces due to the combustible gases generated during EVB thermal runaways. In order to reduce the risk of such secondary fires breaking out, it is important to prevent the formation of explosive atmospheres in such spaces; in some cases, however, it may be impossible to completely stop such atmospheres from forming, which is why it is also just as important to prevent the ignition of such atmospheres when they do form. The following **(1)** and **(2)** are some examples of measures that can be taken to prevent secondary fires.

(1) Since explosive atmospheres (e.g. methane and hydrogen) are typically formed when the combustible gases generated by EVBs mix with the surrounding atmosphere, it is important that ensure vehicle spaces are adequately ventilated to prevent air stagnation and keep the atmosphere of the space below lower explosive limits.

(2) It is also possible to prevent secondary fires and explosions by removing any potential ignition sources when explosive atmospheres form inside vehicle spaces. Other effective measures, such as the provision explosion-protected electrical equipment may also be adopted. However, in cases where explosion-protected electrical equipment is installed within vehicle spaces, it is necessary to make sure to choose the proper type of such equipment and appropriately arrange in consideration of the kinds and characteristics of combustible gases expected to be generated by EVBs of the vehicles stored in the space.

5.2.4 Prevention of Fire Spread

During EVB thermal runaway, exothermic chemical reactions generating heat occur will continue to occur even when it cannot be confirmed that EVB is on fire. EVB thermal runaway also continues until the chemical reaction has finished. Therefore, it is important to implement measures such as the following **(1)** to **(3)** to prevent fires from spreading to surrounding vehicles.

(1) Water spray systems

Water spray systems are system that use water as the fire-extinguishing medium. Since water has excellent cooling effects because of its latent heat of vaporization (i.e. the amount of heat required to change a liquid to gas), and specific heat are high. In addition, it is easy for vessels to ensure sufficient supplies of water for fire-fighting operations because they are surrounded by water during voyages. It is for such reasons water can be said to be an excellent if not the ideal fire-extinguishing medium available. Finally, the spraying of water not only the one vehicle on fire, but also on surrounding vehicles coats them with a water film that helps to effectively isolate any radiant heat that might be generated by a fire. It can be therefore said that water provides excellent fire spread prevention effects.

(2) Water curtains

Water curtains also help create water films by spraying water from fixed nozzles and portable water curtain hoses, and, therefore, also can help isolate radiant heat generated by vehicle fires and prevent the fire from spreading to other vehicles. There essentially two types of water curtains: fixed types and portable types. Portable types use water curtain hoses and provide a greater flexibility of use on deck because they are not permanently installed at a particular location and can be freely moved around. On the other hand, portable systems may be difficult to use depending on the arrangement of the vehicles loaded in vehicle spaces. It is, therefore, necessary to ensure the installation locations of portable water curtain hoses.

(3) Fire blankets

Fire blankets made of fire resistant materials can aid in fire-extinguishing operations because they can be used to isolate vehicles on fire from their oxygen supplies by covering vehicles and creating sealed spaces, but it can be difficult to effectively and completely isolate a vehicle on fire from its oxygen supply because there may be lashing holes (holes in the deck) and lashing belts in vehicle spaces that might make it difficult to completely cover the vehicle. Moreover, although such blankets can help to effectively prevent fire spread due to their excellent thermal insulation effects by using them to cover surrounding vehicles, it is necessary to establish a plan for using them in cases where vehicles are tightly loaded into vehicle spaces.

5.2.5 Fire-fighting Procedures

1 It is extremely important to safely stop any EVB exothermal chemical reactions when responding to electric vehicle fires because of the long period of time typically needed to extinguish EVB fires. The approach to achieving this is to be based on the concept of "burning out" (i.e. not only extinguishing the flames of the EVB fire, but also controlling fire until EVB fire finished completely and stopping any thermal runaway). Since it is possible to gradually stop such chemical reactions and restore temperatures to safe levels before combustible gases and materials are ignited and fire breaks out through EVB cooling, such measures are reasonable and worth serious consideration.

2 It can be difficult to access vehicles on fire in spaces where many vehicles are tightly loaded together and EVBs are installed in the lower sections of vehicle chassis. In such cases, therefore, it is first necessary to extinguish either the vehicle fire or EVB fire as quickly as possible. Once this has been achieved, it is then necessary to prevent thermal runaway by using water from fire hoses or other means to conduct EVB cooling operations.

3 Some EVB cooling measures may make use of fire nozzles or water fog applicators mainly installed on board the vessel for other purposes to supply the water used for EVB cooling operations, while other measures that are specific to such cooling operations (e.g. penetration nozzles) may also be adopted. In the latter case, however, the risk of electric shock when penetrating healthy battery cells using penetration nozzle for supplying water into EVBs needs to be carefully considered.

4 Since it is known that EVB temperature can increase again even after cooling operations have stopped in cases where the EVB's exothermal chemical reaction has not been stopped, it is important to confirm there is not such temperature increase. This can be done either by using infrared cameras or by spraying water onto the EVB battery and checking whether the water is evaporating.

5.2.6 Fire-fighting Operations

1 It is essential for crew members, in principle, to work in groups of at least two or more crew members when tackling fires so as to best ensure safety during fire-fighting operations. Although a single crew member may act in emergency situations where an immediate response is needed (e.g. a fellow crew member is injured or otherwise requires immediate assistance), dangerous situations can often be best avoided by seeking assistance from others because doing so can lower the risk of something important being overlooked or some inappropriate action being taken.

2 Fires typically create situations where visibility is poor due to the effects of smoke. Such conditions may, therefore, make effective fire-fighting operations and the identification of the sources of fires quite difficult. Moreover, such situations may lead to errors in judgement by the firefighters, which in turn could place not only themselves but also others in further danger. For such reasons, it is important to ensure firefighter safety and make it as easy as possible for them to identify a fire's source. One important thing with respect to fire-fighting operations is ensuring proper ventilation of affected spaces because doing so not only allows smoke to be dispersed and visibility to be improved, but it also allows dangerous gases to be diluted and dispersed. Such things not only can directly impact firefighter safety in a positive way, they also can make it much easier to identify fire sources. For such reasons, the installation of ventilation control systems is seen as an effective measure to take in with respect to fire-fighting operations (refer to **5.2.7** for more details on ventilation control). There are, however, risks that need to be considered with respect to such systems. Their use with respect to large-scale fires with low oxygen concentration levels, for example, may actually exacerbate the fire by providing more oxygen to it. It is very important, therefore, to develop fire-fighting plans which take into account ventilation systems in addition to the locations and other conditions related to potential fires.

3 The usage time for the self-breathing apparatuses provided to firefighters needs to be considered due to amount of time typically required for EVB cooling operations. Since the onboard usage time of such apparatuses generally tends to be limited to between 20 and 30 minutes, it is important to create situations in which fire-fighting operations can largely be implemented without needing to use such apparatuses. Although ventilating in the same direction and dispersing smoke can help create such situations, it is also important to establish fire-fighting plans and implement daily fire drills for effective fire-fighting operations expected to take long periods of time. Some further effective measures for fire-fighting operations over long periods are reducing amount of air wastage in self-breathing apparatus air tanks, ensuring a sufficient supply of spare tanks and providing appropriate devices for recharging such tanks.

4 The use of water during fire-fighting operations can in some cases have an adverse effect on vessel stability. It is, therefore, necessary to try and minimize the amount of water accumulating in vehicle spaces by appropriately controlling of the amount of water used during fire-fighting operations and only use the amount considered necessary. One effective way to avoid such problems and also save water is to spray water mist onto EVBs because it provides more effective cooling than jets of water from hoses. When using water, however, it is important to carry out excess water removal operations at the same time as fire-fighting operations so as to prevent excess water accumulation. The main principle for maintaining vessel stability during fire-fighting operations is to either discharge the water used for fire-fighting operations overboard or transfer such water to lowest location on the vessel as far as practicable. Since it is possible that scuppers may become clogged or blocked by burnt residues or other materials in such cases, it is necessary to monitor that scuppers for discharging water are not clogged or otherwise blocked. Furthermore, it is important to establish plans for using discharge devices, such as fixed pumps, eductors, etc. in advance.

5.2.7 Ventilation Control

1 Some approaches to containing fires advocate isolating the fire by shutting down ventilation systems in affected spaces. Such approaches may be effective in the case of fires in enclosed spaces where an oxygen-deficient environment can be more easily created. On the other hand, the possibility of creating such an environment in larger, more open spaces (e.g. vehicle spaces) tends to be fairly low, and the shutting down of ventilation systems may lead to the space filling up with smoke, thus making the situation more dangerous. It is, therefore, important to consider whether ventilation is needed during fire-fighting operations because in some cases ventilation can be an effective measure for ensuring visibility and firefighter safety, particularly with respect to the identification of vehicles on fire and fire-fighting operations in vehicle carrier cargo spaces.

2 It is possible to ventilate vehicle spaces using exhaust or supply type ventilation systems because it is often necessary to carry out smoke dispersal operations at the same time as fire-fighting operations due to huge amount of smoke typically generated by vehicles on fire. The purposes of such operations are as following **(1)** to **(3)**.

(1) Improve visibility for firefighters and also ease in the identification of fire sources and the locating of crew members unable to escape from affected spaces for whatever reason (e.g. injuries, blocked escape routes).

(2) Reduce the risk of high temperature combustible and toxic gases.

(3) Reduce the possibility of flashovers and backdrafts.

3 Although it is important to carry out smoke dispersal work during fire-fighting operations, there may be areas where the air stagnates due to ventilation arrangements and directions of openings in vehicle spaces. For such reasons, it is important to verify the ventilation conditions in the vessel and understand how air circulates throughout. This can help identify potential problem areas in advance and allow additional measures that improve the ventilation condition to be adopted. For example, adopting the following **(1)** and **(2)** additional measures in advance can lead to improved ventilation conditions in vehicle spaces.

(1) Positive pressure ventilation: Create positive pressure in vehicle spaces so as to help effectively disperse smoke

(2) Forced ventilation using portable fans: Help prevent air stagnation from occurring by improving

air circulation using portable fans

5.2.8 Fixed Fire-extinguishing Systems

1 Although it is important to quickly commence initial fire-fighting operations upon detecting a fire, it can be, depending upon the scale of the fire, more effective to activate fixed fire-extinguishing systems as soon as possible. In such situations, it is important to decide the target times from alarm activation to system activation in advance. It is also important to consider situations in which fire-extinguishing systems may need to be re-activated after fire-extinguishing operations have been completed due to the possibility of EVB thermal runaway causing new fires to break out. It can, however, be quite difficult if not impossible to grasp the fire situation in vehicle spaces when there is no monitoring system installed. In such cases, crew members need to access the affected spaces to confirm the fire's situation and re-activate fire-extinguishing system (if necessary). Since such operations can expose crew members to additional risks, it is essential to be able grasp the situation in vehicle spaces through remote means.

2 The following **(1)** to **(3)** are three types of fixed fire-extinguishing systems considered acceptable for installation in vehicle spaces. When adopting any of these systems, it is important to understand what they are each capable of doing in cases where they are activated in response to electrical vehicle fires with EVB thermal runaway. For example, it needs to be noted that thermal runaway and combustible gas generation is likely to continue until the EVB has been sufficiently cooled.

(1) High expansion foam fire-extinguishing systems
This type of system extinguishes fires through the cooling and smothering effects of high expansion foam. Since foam, however, has the tendency to break down when exposed to heat or when subject to impact, it is necessary to consider the prolonged duration of thermal runaway and the need for re-application of foam when installing such systems in vehicle spaces. Moreover, since there currently exist no devices or systems specifically intended for the monitoring the amount of foam released into such spaces, the adoption of effective alternative monitoring measures, such as level gauge measuring, needs to be considered. Furthermore, foam breakdown due to water from the fire hoses used by crew members re-entering affected spaces is possible.

(2) Carbon dioxide fire-extinguishing systems
This type of system extinguishes fires by smothering them and depriving them of oxygen. Such an approach can be used to extinguish vehicle fires, but exothermic chemical reactions can, in some cases, continue even in such inactive situations because thermal runaway can continue without oxygen. In addition, a fire may re-ignite if carbon dioxide leaks out due to weak airtightness and the oxygen concentration inside the affected space increases. Installation of oxygen detector and re-application of carbon dioxide to prevent re-ignition or ensure to close the opening spaces to enhance airtightness of such spaces may be effective measures. It is necessary to consider re-application of carbon dioxide because it is difficult to crew members re-entering the spaces which is released carbon dioxide.

(3) Water-based fire-extinguishing systems
This type of system extinguishes fires through the cooling effects of spraying water. Water has excellent cooling effects, and it can be an effective way of cooling EVBs with thermal runaway. It can, however, be difficult to directly spray water onto EVBs installed in electric vehicles because EVBs are typically installed in lower sections of vehicle chassis. Even so, spraying water on vehicles surrounding a vehicle on fire can be an excellent way of preventing fire spread. When adopting such systems, the arrangements of nozzles need to be carefully considered in

advance to ensure that such systems are just as effective in the case of vehicles with roofs or tops close enough to the ceilings of vehicle spaces to obstruct the spray of water from nozzles.

3 Another approach that is sometimes taken is to use a combination of different systems so as to provide complementary extinguishing effects. For example, carbon dioxide systems may be complemented the cooling effects of water-based fire-extinguishing systems. In such cases, however, it is necessary to carefully design the installation of such systems to ensure their effects complement one another instead of cancelling out one another. For example, foam generated by high expansion foam fire-extinguishing systems may lose its effectiveness when impacted by water sprayed from water-based fire-extinguishing systems due to the water-based system being mistakenly activated in spaces already filled with foam. For such reasons, it is necessary to consider in advance the effective implementation of such a combination approach based on an understanding of the characteristics, effectiveness and weaknesses of each system intended to be used.

5.2.9 Improvement of Operational Reliability for Fixed Fire-extinguishing Systems

Designing fixed fire-extinguishing systems to ensure they can be activated without causing damage and without malfunctioning is one effective way of improving operational reliability. The probability of fire-extinguishing operations being successfully carried out increases when relevant systems can be reliably activated during fires. It is, therefore, necessary to understand the specifications and structure of a system in order to improve its operational reliability. For example, it is important to design systems based on selected items to be improved after analyzing the causes, risks, frequencies, etc. of various system failure scenarios.

5.2.10 Other

1 There may be other measures that can be taken to prevent electric vehicle fires. One of these could be to simply not load electric vehicles which are seen as high fire risks. For example, electric vehicles failing to meet the recognized standards for loading as cargo are not loaded on board the vessel. With the continued widespread adoption of electric vehicles, there may eventually be a method established for objectively evaluating EVB condition, and acceptability for loading could be assessed based upon that condition. Prior to loading, EVB condition related data could be analyzed, and limitations could be placed upon the loading of vehicles whose EVBs were considered to a high fire risk. In addition, indicators corresponding to EVB condition might also be established and incorporated to aid in the assessment process.

2 Measures identifying areas in need of enhanced fire safety measures could also be adopted, and the loading of electric vehicles in such areas could then be restricted. In addition, labelling electric vehicles as such might make them easier to identify and, thus, distinguish from gasoline-powered vehicles. This could, in turn, allow faster identification of the type of vehicle on fire and help ensure that fire-fighting operations appropriate for the type of vehicle fire are being carried out.

5.2.11 Fire-fighting Tactics

It is necessary for stakeholders to come together and discuss items like those specified in this chapter so that they can establish effective fire-fighting tactics for each vessel and each type of loaded cargo. It is especially important to prepare in advance fire-fighting procedures which include information on operational methods and important points of the fire-extinguishing systems to be adopted, the timing and procedures for the fire spread prevention methods to be adopted, guidelines regarding the use of ventilation during fires, etc. In addition, it is important to consider which fire-fighting procedures can be implemented safety depending upon the actual state of the vessel at the time. **Appendix 1** is an example of flow chart approach that be adopted to help develop suitable fire-fighting tactics in advance.

5.2.12 Means of Escape from Vehicle Carriers

Even if the fire safety measures described so far are taken, the state and scale of a fire cannot be predicted; in the worst-case scenario, the ship's crew may even be forced to escape from the fire via lifeboats and liferafts. From the viewpoint of ensuring the safe escape of the ship's crew in such scenarios, risk assessments are important way to help to identify any associated hidden risks. The Society conducted a risk assessment in cooperation with stakeholders, assuming a scenario in which a fire broke out in the cargo hold, to identify what risks could be present in the event of an escape from the vessel and to study countermeasures to deal with these risks.

Since lifeboats and liferafts are installed on the upper decks of vehicle carriers, escape via the upper deck is necessary. Furthermore, since accommodation blocks are located above cargo holds and the upper deck can be affected by cargo hold fires, there are many scenarios in which a cargo hold fire can interfere with escape. For these reasons, it is necessary to pay careful attention to matters associated with escaping from the lower deck and engine room of a ship because such escapes can be easily affected by a cargo hold fire due the use of staircases and escape trunks adjacent to the cargo hold.

(Note) The Society has compiled the results of a risk assessment it carried out related to measures that can be implemented for the purpose of ensuring safe escape from vehicle carriers affected by cargo hold fires. This "Risk Assessment related to the Safe Escape from a Car Carrier" is available on the Society's official website (Home > Products & Services > Safety Measures for Maritime Transportation of Electric Vehicles). It summarizes such measures for reference, but does not require implementation of the measures described in this risk assessment.

5.3 Affixation of Class Notation

5.3.1 General

The plans and documents related to the affixation of the following notation that need to be submitted to the Society for reference and approval are specified in **Table 2.1**.

5.3.2 Fire Detection (AFVC(FD)(EV))

The notation "AFVC(FD)(EV)" can be affixed to the classification characters of vessels adopting effective measures for the early detection of electric vehicle abnormalities and fires, and the early identification of vehicles on fire in accordance with **5.2.2**; however, the effectiveness and usefulness of such measures are to be examined and verified in advance.

5.3.3 Secondary Fire Prevention (AFVC(PS)(EV))

The notation "AFVC(PS)(EV)" can be affixed to the classification characters of vessels adopting effective measures for the prevention of electric vehicle abnormalities and fires, and the prevention of secondary fires in accordance with **5.2.3**; however, the effectiveness and usefulness of such measures are to be examined and verified in advance.

5.3.4 Fire Spread Prevention (AFVC(PFS)(EV))

The notation "AFVC(PFS)(EV)" can be affixed to the classification characters of vessels adopting effective measures for the prevention of fire spread after electrical vehicle fires in accordance with

5.2.4; however, the effectiveness and usefulness of such measures are to be examined and verified in advance.

5.3.5 Fire-fighting Operations (AFVC(FF)(EV))

The notation "AFVC(FF)(EV)" can be affixed to the classification characters of vessels adopting effective measures for fire-fighting operations after electrical vehicle fires in accordance with **5.2.5**, **5.2.6**, **5.2.7**, **5.2.8** and **5.2.11**; however, the effectiveness and usefulness of such measures are to be examined and verified in advance.

5.3.6 Enhanced Fixed Fire-extinguishing Systems (AFVC(EFF)(EV))

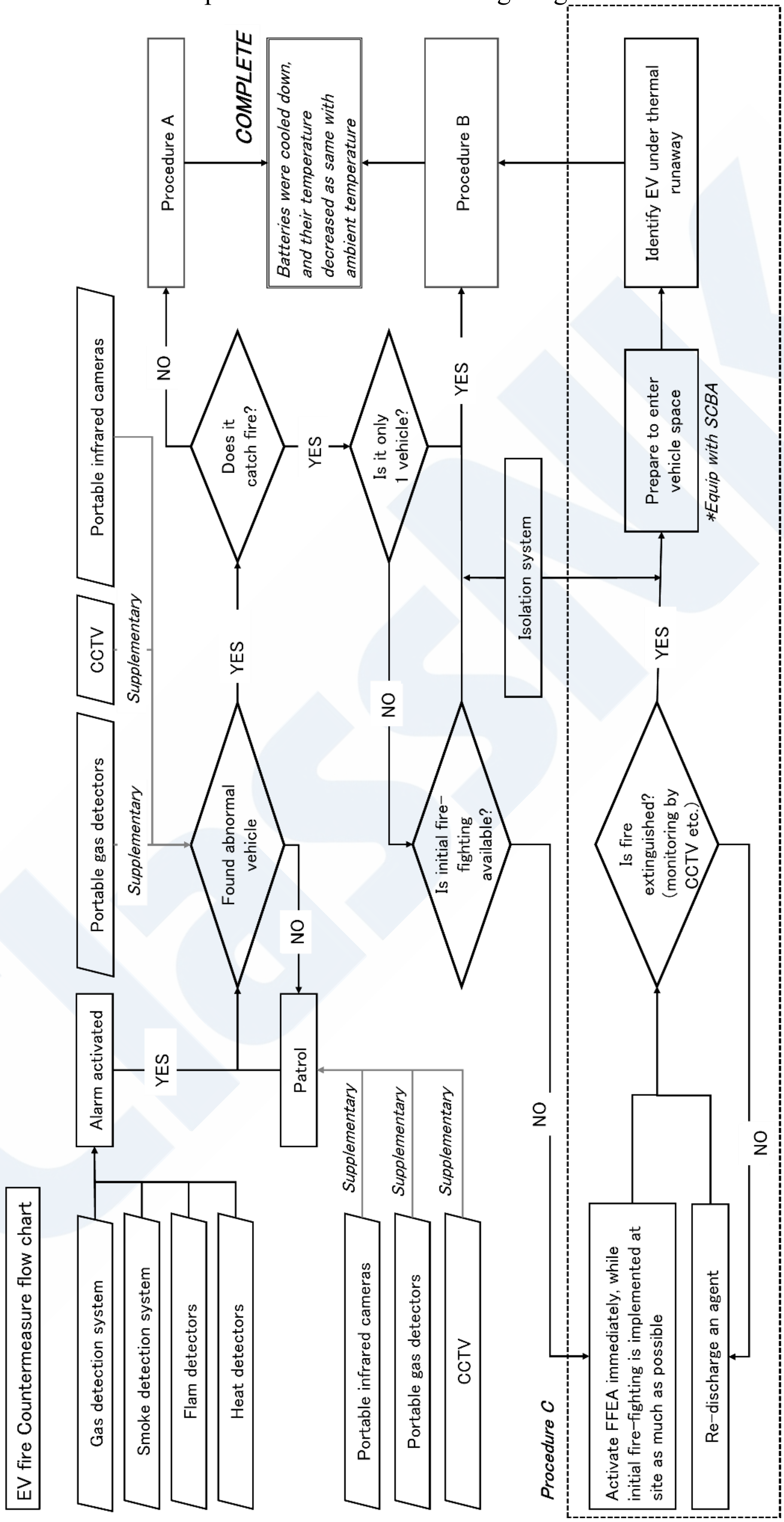
The notation "AFVC(EFF)(EV)" can be affixed to the classification characters of vessels adopting effective measures for the improvement of operational reliability for fixed fire-extinguishing systems in accordance with **5.2.9**; however, the appropriateness of such measures is to be examined and verified in advance.

5.3.7 Safety Escaping from Vehicle Carrier (AMEVC(EV))

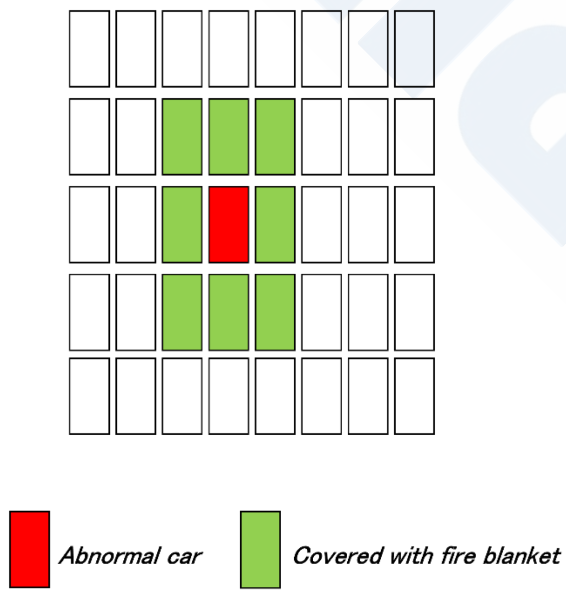
The notation "AMEVC(EV)" can be affixed to the classification characters of vehicle carriers adopting effective measures for the improvement of escaping in case of fire in cargo hold in accordance with **5.2.12**; however, the appropriateness of such measures is to be examined and verified in advance.

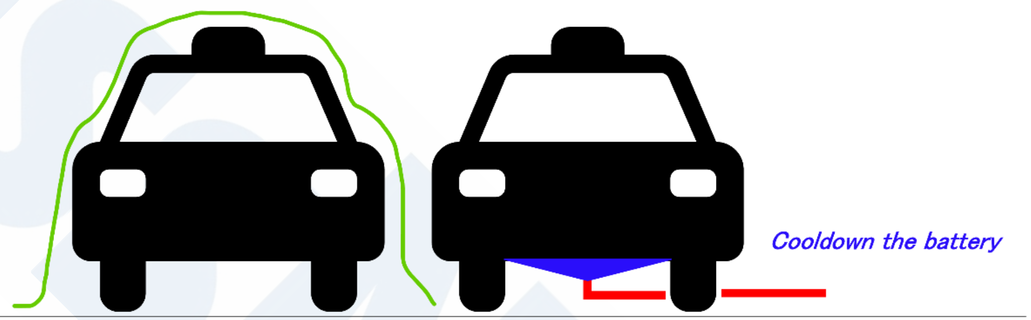
Appendix 1

Example of flow chart for fire-fighting tactics



Procedure A

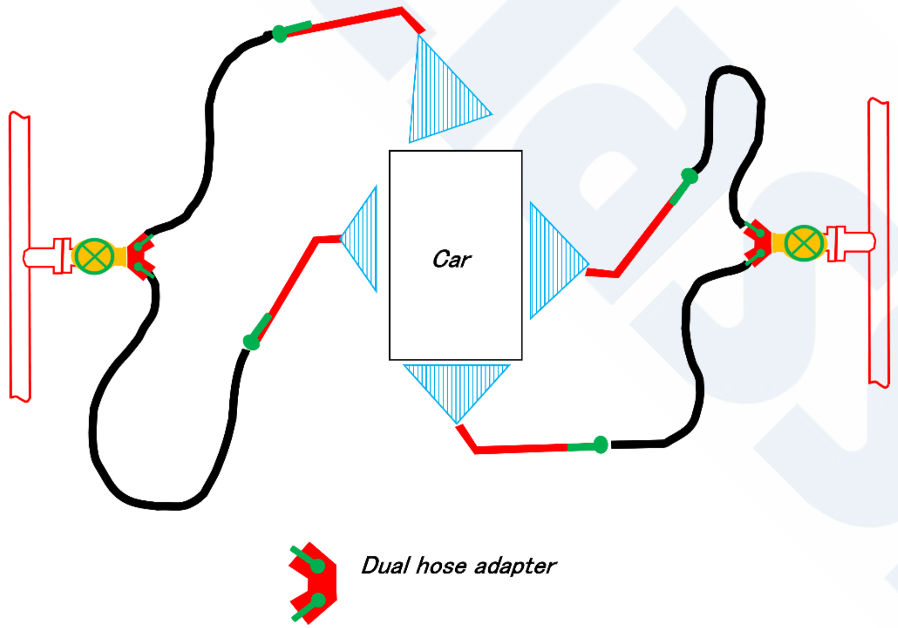


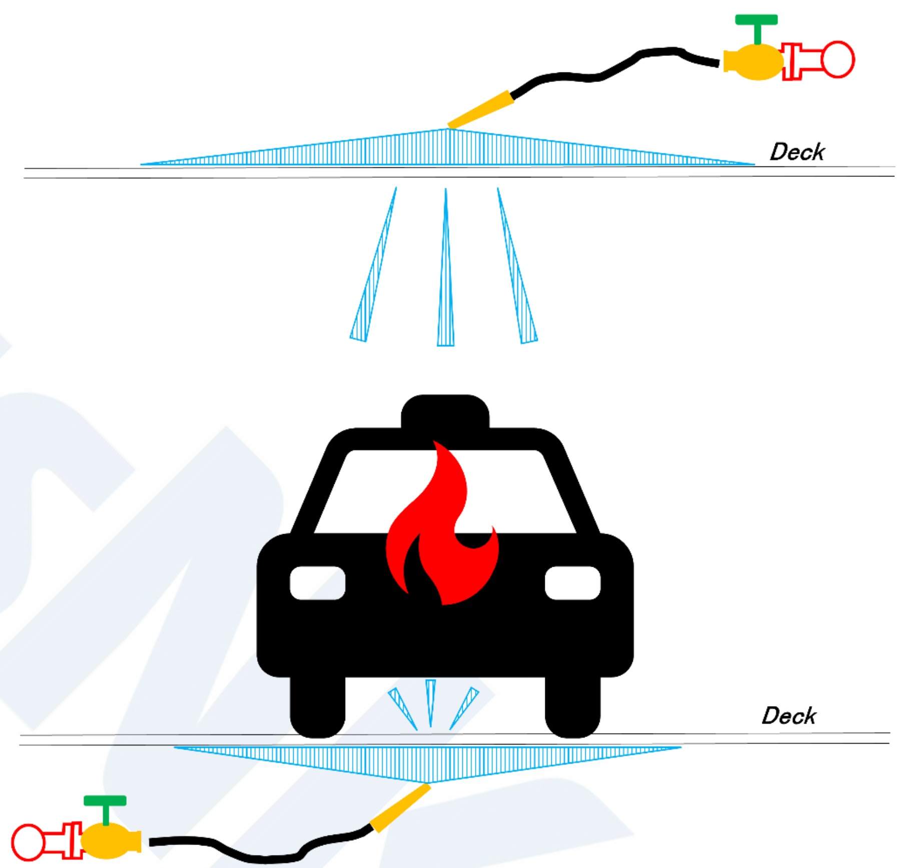


Isolation of abnormal vehicle
-Remove lashing belt for abnormal vehicle (If possible)
-Cover the vehicles around abnormal vehicle with fire blanket
-Activate ventilation systems in vehicle spaces (dilution of generated gases)
-Cooling battery using water fog applicator

Reason for no covering abnormal vehicle with fire blanket
There has possibility that the combustible gases are reached to explosion area because there may generate flammable gases from abnormal vehicle
It means it is better no covering the vehicles with abnormal battery

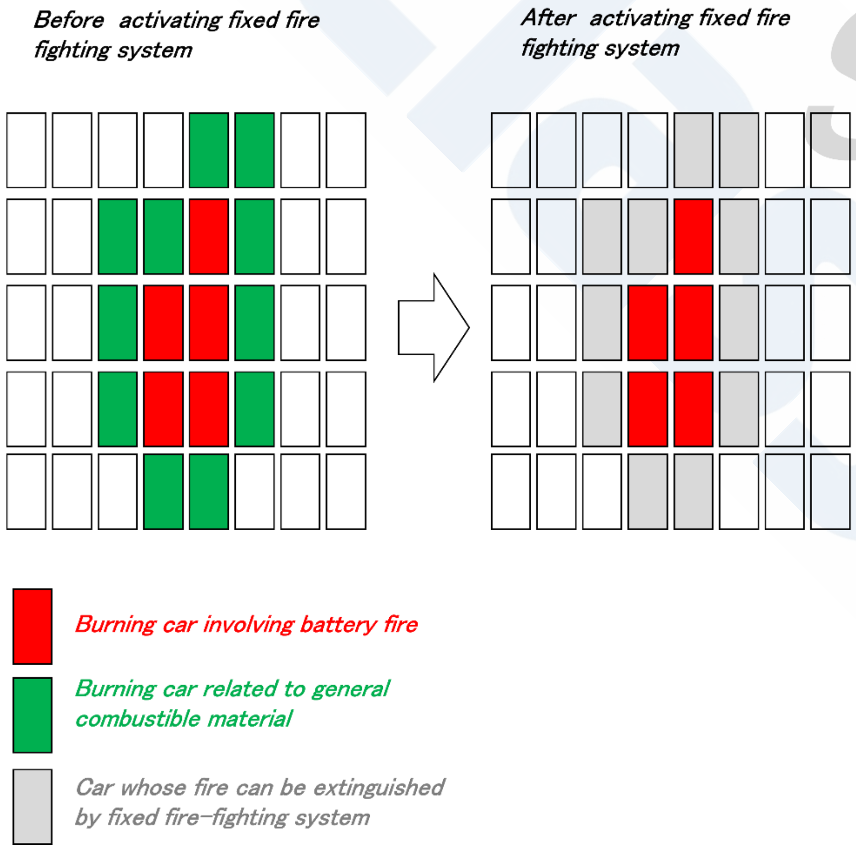
Procedure *B*





-Implement initial fire-fighting after checking fire situation.
-Prepare as below items.
①Dual hose adapter
②Water fog applicator
③Fire hose
＜Discharge water＞
Note : Discharge water to vehicle with fire using lashing holes on decks with lashing holes.

Procedure C



There may mix electrical vehicle fire with battery thermal runaway and general fire such as burning tires and seats in the event of a fire occurring in vehicle carrier.

It is effective approach to activate fixed fire extinguishing system in case that scale of general fire is huge, means impossible to initial fire–fighting.

The primary purpose of fixed fire extinguishing system is extinguishing of general fire, but not extinguishing of battery fire.

To be confirm the re–ignition after fire extinguishing.

Commence the fire–fighting to electrical vehicle fire after identifying vehicle with battery fire.

It is effective approach to activate water curtain to necessary areas to isolate the vehicles with fire and healthy vehicles if the vessel is installed water curtain.

Please contact the following regarding any questions or comments related to this Guidelines

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