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GUIDELINES FOR THE SAFE CARRIAGE OF ALTERNATIVE FUELED VEHICLES (AFVS) ON RO-RO SHIPS AND ON BOARD CHARGING OF ELECTRIC VEHICLES

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1 GENERAL ASSUMPTIONS

1.1 Purpose

The purpose of this *Publication* is to provide recommendations for the safe carriage of AFV fuelled vehicles on ro-ro ships (passenger, cargo, including car carriers), as well as for charging electric vehicles on board ships.

This *Publication* is based on the EMSA document "Guidance for the safe carriage of alternative fuel vehicles (AFV) in ro-ro spaces of cargo and passengers ships", dated 23/05/2022, taking into account the information provided in other source documents listed in the Schedule.

1.2 Application

These *Guidelines* apply to new and existing ro-ro ships for the carriage of all types of vehicles referred to as AFV. These *Guidelines* contain design recommendations as well as operational guidelines and procedures intended for owners/ operators and ship's personnel.

Vehicles defined as AFVs include vehicles powered by: liquefied hydrocarbon gas - LPG, natural gas (liquefied - LNG, compressed - CNG), hydrogen (compressed - H_2 and fuel cells - FCEV), as well as electric vehicles - EV (powered only from battery - BEV, hybrid - HEV).

1.3 Abbreviations

AFV	Alternative Fuel Vehicles
BEV	Battery Electric Vehicle
BLEVE	Boiling Liquid Expanding Vapor Explosion
CBG	Compressed Bio Gas
CCTV	Closed-Circuit Tele Vision
CNG	Compressed Natural Gas
DME	Dimethyl Ether
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicles
HEV	Hybrid Electric Vehicle
HF	Hydrogen Fluoride
ICE	Internal Combustion Engine
IMDG	International Maritime Dangerous Goods
IR	Infrared
ISM	International Safety Management (Code)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MED	Marine Equipment Directive
OEM	Original Equipment Manufacturer
PCC	Pure Car Carrier
PCTC	Pure Car Truck Carrier
PRV	Pressure Relief Valve
PRD	Pressure Relief Device
SoC	State of Charge
TPRV/TPRD	Temperature Pressure Relief Valve/Device
TR	Thermal Runaway

1.4 Basic principles

1.4.1 Risk assessment

A risk assessment should be conducted for each ship to ensure that risks arising from the carriage of the AFVs that might affect persons onboard, the environment, the safety of the ship are addressed. These risks should be managed within the framework of existing requirements in the ISM code. The result of the risk assessment should be a ship specific Risk Management Procedure to be carried onboard for the prevention and mitigation of fire incidents involving AFV.

The risk assessment should be prepared taking into account the documents: "Risk assessment as required by the IGF Code - IACS Rec. 146 "and" Risks associated with alternative fuels in road tunnels and underground garages - SP Technical Research Institute of Sweden" or other applicable documents accepted by the Administration of the ship's flag state.

When carrying out the risk assessment, the additional hazards associated with the transport of AFV as defined in section 1.4.2 should be taken into account.

1.4.2 Additional risks in relation to AFV

The following list contains simplified information on energy carriers specific events and hazards - see "Fire-fighting of alternative fuel vehicles in ro-ro spaces, RISE (2019)". More detailed information can be found in the report - "Risks associated with alternative fuels in road tunnels and underground garages, SP (2017)".

.1 Liquid fuels (diesel, gasoline or ethanol):
- fuel tank integrity loss:
  - increase in fire size;
  - pool fires (consider alcohol and fuels other than gasoline/diesel).

.2 Liquefied fuels (LPG, LNG, liquefied DME):
- venting of boil-off gas (for LNG only);
- jet flames from activated PRV;
- gas tank integrity loss;
  - increase fire size and fire propagation;
  - BLEVE;
  - pressure vessel explosion;
  - fire ball.
- gas leak:
  - gas explosion under the following conditions:
    - there are thermal effects (flash fire) if there is ignition of flammable gas cloud in unconfined and non-congested space; or
    - there are pressure effects (VCE = Vapour Cloud Explosion) if there is ignition of flammable gas cloud in confined and congested space.

.3 Compressed gas:
- CNG/CBG:
  - jet flames from activated PRD;
  - gas tank integrity loss:
    - severe increase in fire size and propagation;
    - pressure vessel explosion;
    - fire ball.
  - gas leak:
    - gas explosion (if gas can be accumulated for a while before being ignited)

.4 Hydrogen (compressed or in fuel cells):
- much higher tank pressure than CNG which may lead to leaks, and in turn to accumulation of flammable or even explosive hydrogen air mixtures for a short period;
- rupture of pressure tank can cause very high concentrations of hydrogen in the vicinity of the car. In open spaces, this will cause a combustible mix to form for a short period. Enclosed spaces could accumulate enough hydrogen-air mixture for a large explosion;
- more ignitable, higher flammability and explosivity than conventional fuels and natural gas.

.5 Batteries:
- increase in fire size and propagation;
- small jet flames;
- toxic gases;
- gas explosion (if the released gas can be accumulated for a while before being ignited);
- long lasting re-ignition risk (can ignite or re-ignite weeks, or maybe months after the provoking incident);
- difficult to stop/extinguish.

It should be noted that the presented risks form a list of possible events without ranking their severity or probability of occurrence. It is expected that incidents related to new risks of AFVs will have a significantly low probability of occurrence due to the built-in safety barriers of these vehicles.

1.4.3 Reference to the IMDG Code

AFV, while being transported on ships, are treated as dangerous goods, subject to the IMDG Code.

This section provides an overview of the currently applicable provisions from the IMDG Code in relation to AFVs.

According to the IMDG Code, section 2.9.2, EVs shall be classified as "UN 3171 - BATTERY POWERED VEHICLE". Similarly, the remaining AFV shall be typically classified as "UN 3166 - FUEL CELL, FLAMMABLE GAS VEHICLE" or "UN 3166 - FUEL CELL VEHICLE, FLAMMABLE LIQUID".

Special provision SP 961 of Chapter 3.3 of the IMDG Code states that the Code shall not be generally applicable for AFVs carried in a special category, vehicle and ro-ro spaces or on the weather deck of a ro-ro ship as long as there are no signs of leakage from the battery, engine, fuel cell, compressed gas cylinder or accumulator, or fuel tank when applicable. When the vehicle is stowed in a cargo transport unit (container), the exception does not apply to container cargo spaces of a ro-ro ship.

1.4.3.1 Electric vehicles (EV)

For EVs (both HEVs and BEVs), the lithium batteries shall meet the provisions of 2.9.4 of the IMDG Code.

Where a lithium battery installed in a vehicle is damaged or defective, the battery shall be removed. If the battery is not removed, the vehicle should not be accepted for transport. A removed damaged battery should be transported in accordance with the provisions of SP376 of Chapter 3.3 of the IMDG Code.

If an EV is found damaged but it is unclear if the battery is damaged, it is recommended to apply this provision and do not accept the vehicle ~~it~~ for transport.

1.4.3.2 Gas vehicles

Section 1.1.3.1 of the IMDG Code states that any article (in this case the vehicle) which, as presented for transport, is liable to produce flammable gases or vapours under normal conditions of transport is forbidden for transport.

Vehicles powered by a flammable gas (liquefied or compressed) shall not be subject to the provision of the IMDG Code only if the vehicles are stowed in the vehicle, special category and ro-ro spaces or on the weather deck of a ro-ro ship, or in a cargo space designated by the Administration (flag State) in accordance with SOLAS, reg. II-2/20, as specifically designed and approved for the carriage of vehicles, and there are no signs of leakage from the compressed gas cylinder or accumulator, or the fuel tank(s) are empty and the positive pressure in the tank does not exceed 2 bar, the fuel shut-off or isolation valve is closed and secured, and installed batteries are protected from short circuit.

With sufficient holding time (the time before the pressure release valve will open), the LNG-vehicle is not liable to produce flammable gases or vapours and therefore should be accepted for transport. The holding time can be determined by using a chart available from the car manufacturer, after taking readings of fuel tank level and pressure from the vehicle. It can also be considered whether this can be simplified by a method established using only tank pressure.

For transport of CNG vehicles in vehicle carriers, see MSC.1/Circ.1471 RECOMMENDATION ON SAFETY MEASURES FOR EXISTING VEHICLE CARRIERS CARRYING MOTOR VEHICLES WITH COMPRESSED HYDROGEN OR NATURAL GAS IN THEIR TANKS FOR THEIR OWN PROPULSION AS CARGO.

1.4.3.3 Small electric vehicles

According to the provisions of the IMDG code small EVs such as electric scooters, bicycles and kick bikes shall be classified as “UN 3171 BATTERY-POWERED VEHICLE or BATTERY-POWERED EQUIPMENT”. Special provision SP 388 specifies that battery powered vehicles are self-propelled apparatus designed to carry one or more persons or goods, for example bicycles (pedal cycles with a motor) and self-balancing vehicles (such as segways).

Special provision SP 961 states that those vehicles are not subject to the provisions of the IMDG Code if they are stowed in the vehicle-, special category and ro-ro spaces or on the weather deck of a ro-ro ship or in a cargo space fulfilling the requirements of SOLAS, reg. II-2/20. If these conditions are not met, the vehicles shall be assigned to class 9 and fulfil the provisions of the IMDG Code.

2 APPLICATION TO RO-RO PASSENGER SHIPS

2.1 Stability checks and loading limitations

EVs are assumed to be on average 25% heavier than similarly sized conventional vehicles and have a lower positioned center of gravity. When loading EVs, this should be taken into account when calculating the load and stability of the ship.

2.2 Precaution against ignition

2.2.1 Identification of vehicles

Information on the type of fuel or energy supply in the transported vehicles should be provided during booking the transport and confirmed at the check-in, if possible. The ship’s Operator should update in the most appropriate manner its website/vehicle booking system, as appropriate.

The ship's crew should be able to quickly identify the type of AFV (type of fuel or energy supply) based on the information provided.

It is recommended that AFVs entering the ship be marked with a self-adhesive sticker/ card hung on the side mirrors, with the symbol of the fuel/ energy carrier used (CNG, LPG, LNG, EV, H_2, FCEV) in order for the crew to easily identify the hazard during transport and to use appropriate extinguishing agents/ procedures in the event of an emergency.

The shipowner/ operator may require additional vehicle identification.

2.2.2 Conditions for carriage

AFVs should only be allowed onboard if they comply with the provisions of the IMDG Code as also described in1.4.3. Particular attention should be paid to the following:

.1 if there is suspicion that the battery of EV is damaged or their battery is defective, they should only be allowed transported on a trailer if their battery is removed;
.2 the vehicles are free from any leakages of fuel/gases.

2.2.3 Stowage of AFVs on board the ship

AFVs should be stowed in such a way that fire patrols will have direct access to all such vehicles.

It is recommended that in a ro-ro/ special category space, the AFV parking area should be separated from the area for other conventional vehicles by a free space, for example, a transverse passage with a width of approx. 1.5 m.

2.3 Fire/ gas detection

2.3.1 Fixed means of fire/ gas detection

Ro-ro spaces and special category spaces intended for the carriage of AFVs should be fitted with properly installed fire and/ or gas detectors.

2.3.2 Video monitoring

2.3.2.1 In ro-ro spaces and special category spaces, effective CCTV surveillance systems shall be provided for the purpose of continuous monitoring of these spaces with the use of video cameras, with the possibility of immediate playback of the recording, in order to enable quick identification of the source of the fire, as far as practicable. It is not required to ensure continuous video observation by the crew.

2.3.2.2 CCTV systems are intended to be helpful in quickly confirming a fire and determining its location after activation of a fire alarm, as well as in promptly taking appropriate fire-fighting actions. The video image can be helpful in determining the correct section of the water sprinkler system to be activated on the car deck, as well as in taking appropriate manual fire- fighting measures by the fire team.

2.3.2.3 AFVs should be stowed in a position where the images from such CCTV systems are not obstructed from other vehicles or ship's structures.

2.3.3 Fire patrols

.1 Crew members on fire patrol duties should be familiarized in the basic characteristics and safety aspects of AFVs. Fire patrol is to be skilled in routines for emergency disconnection of charging EVs.

.2 Fire patrol routes should be arranged in such way that cargo spaces with a high content of AFVs, such as, but not limited to, spaces designated to EV charging, are well covered.

.3 A portable IR camera should be carried at all times and should be used regularly by the patrol team. The portable gas detectors described in 2.5.3 should be available for use on suspicion of gas leak during the fire patrols.

.4 In addition to general signs of fire or elevated risk of ignition, fire patrols should be especially alert to AFV related signs of instability such as:

- smoke / heat emitted from parts of vehicle where a battery is normally located;
- popping sounds from battery cells caused by TR;
- sounds related to opening of over pressure valves on CNG or LNG tanks;
- any observation of tank pressure manometer values indicating tank pressure close to pressure relief limit;
- gas smell;
- suspected unauthorized connection to ship electric system for charging of batteries.

.5 On suspicion of unstable behavior of an AFV, in terms of fire safety, the fire patrol should take safety precautions such as keeping a safe distance and avoidance of potentially hazardous gases.

2.3.4 Risk Management Procedures

Ship's procedures should take into account all factors related to the handling and loading of AFVs that pose additional specific hazards to the ship.

Ship procedures should ensure that the driver/owner of the AFV is aware of the need to inform the ship's crew if he becomes aware of anything unusual about their vehicle, e.g. error/ warning message on the car's dashboard. Such information should be communicated to the crew without delay.

Procedures should include information that when AFVs are stowed in ro-ro/ special category spaces, no repair work may be carried out in such spaces, bearing in mind the activities that involve use of naked flames or sources of ignition.

The Risk Management Procedure, mentioned in 1.4.1, should also cover the emergency response part that should be included in the Decision Support System required by SOLAS, reg. III/29.

2.4 Fire extinguishment

2.4.1 AFVs emergency response procedure

2.4.1.1 Emergency response procedures and contingency plan

The procedure should include the activation of a fixed water spray system by the crew as a preferred first response to a fully developed fire. However, under certain circumstances, a first response with manual extinguishing agents may be effective. Additional information on emergency response procedures is provided in the Annexes to these Guidelines.

The response procedures should include, but not be limited to, the following:

.1 mitigation actions for all specific foreseeable hazards caused by a fire involving AFVs;

.2 the number, the type and capacity of fixed and portable equipment (local water cooling etc) of the fire-fighting team;

.3 the appropriate smoke strategy to ensure the operation of the fire-fighting team and avoiding a fire growth, also taking into account the type of ro-ro/special category space;

.4 a strategy to contain the fire;

.5 fire-fighting team strategy, taking into consideration the possibility of entering a space with toxic gases (e.g. HF in the case of EVs), procedures for decontamination of firefighters and handling of contaminated clothes and equipment after the operation;
.6 post fire routine, to prevent reignition;
.7 the activation and operation of fixed fire-fighting system, in combination with appropriate ventilation system operation.

2.4.1.2 Drills (specific for AFVs)

A fire drill using a scenario involving AFVs should be carried out onboard at least every two months. Such a fire drill should follow the requirements under SOLAS, reg. III/19.3 and III/30.

2.4.2 Protective clothing of firefighters

Compared to conventional vehicles, AFVs do not, to today's knowledge, introduce any additional specifications of the fire suits. The suit should be certified according to EN 469:2020 and fulfil level 2 for heat protection, water penetration and water vapor resistance (indicated with X2, Y2 and Z2). Note that MED also allows level 1, which has a lower level of protection and should not be used during fire suppression of EV. Furthermore, the firefighter should wear a hood (balaclava), to protect exposed areas of the head and neck. Such hoods are not (yet) included in MED and can instead be approved according to EN 13911:2017. Full-coverage clothing should be worn under the suit, and it is recommended that the fire station is equipped with such additional clothing for any firefighter arriving without wearing long sleeves/ legs.

2.4.3 Portable fire-fighting equipment

In addition to fire extinguishers and equipment required for ro-ro/ special category spaces in SOLAS, reg. II-2/20, the ship shall be equipped with the following fire-fighting equipment:

- 25 kg mobile powder extinguisher with a 5 m long hose (generally intended for extinguishing a leaking gas fire, C group of fire) - 1 pc.
- 20-liter mobile foam extinguisher, with a 5 m long hose (generally intended for extinguishing a spilled liquid fuel fire, B group of fire) - 1 pc.
- 20 kg portable CO_2 fire extinguisher with a 5 m long hose (mainly intended for extinguishing electrical systems and equipment) - 1 pc.
- extinguishing crowbar (for emergency opening of the car door/ engine cover by firefighters) - 1 pc.
- water mist lance (for piercing the car cover and giving water mist by a fireman to the closed space of the car under fire) - 1 pc.
- thermal imaging camera - 2 pcs.
- specialized fire blankets, such as car covers or textile sheets (to be put on a burning car and cut off the air supply) - 4 pcs.

Fire extinguishers and fire blankets should be stored in an easily accessible place near the AFV stowage area.

2.4.4 Communication of firefighters

Helmets of firefighting equipment, required in SOLAS, chapter II-2, should be equipped with a radio communication system with the control station (safety center, if provided) and between the firefighters of the firefighting team. Additionally, the helmet should have a built-in flashlight, enabling adequate lighting of a darkened and smoky space, without occupying the hands of a firefighter.

2.5 Carriage of AFVs with compressed hydrogen (H_2) or natural gas (LNG) (CNG) in their tanks for their own propulsion as cargo

2.5.1 Carriage on open decks

It is recommended that AFVs with compressed hydrogen or natural gas be carried on open decks or in open ro-ro spaces.

2.5.2 Carriage in closed cargo spaces

If these vehicles are carried in closed ro-ro spaces/ special category spaces, the ventilation and electrical equipment in these spaces shall meet the requirements of SOLAS, reg. II-2/20-1.3 and 20-1.4, as amended, as is given below.

2.5.2.1 Electrical equipment and wiring

All electrical equipment and wiring should be of a certified safe type for use in an explosive hydrogen and/ or methane-air mixture*.

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* Refer to the Recommendations of the International Electrotechnical Commission, in particular publication IEC 60079.

2.5.2.2 Ventilation

Electrical equipment and cables, if installed in any duct of the space for the carriage of AFVs, should be certified as safe for use in an explosive hydrogen and/ or methane-air mixture.

Fans should be designed in such a way as to exclude the possibility of ignition of the mixture of hydrogen and/ or methane with air. Suitable wire mesh shields should be provided over the inlet and outlet vents.

2.5.3 Portable gas detectors

There should be at least two portable gas detectors on board as specified in SOLAS, reg. II-2/20-1.5. Such detectors should be suitable for the detection of gaseous fuel and should be certified safe for use in an explosive gas-air mixture.

2.6 Carriage of electric vehicles (EVs)

2.6.1 The stowage of EVs on board the ship

Due to other fire risk features and the extinguishing media used, it is recommended that EVs powered by battery only (BEV) should be separated from hybrid electric vehicles (HEV).

2.6.2 The carriage of EVs other than cars

2.6.2.1 Larger EVs such as trucks, vans and commercial vehicles should be treated in the same way as electric cars with consideration given to the firefighting methods appropriate to the vehicle type.

2.6.2.2 Small EVs, such as scooters, bicycles, kick scooter, should be transported on the open deck or in ro-ro/ special category spaces that meet the requirements specified in SOLAS reg. II-2/20.

2.6.2.3 Any small EV with modified batteries (non-factory) should not be allowed to charge on board due to the increased risk of fire or explosion.

2.6.2.4 Small EVs should be secured effectively to avoid movement during transit.

2.6.3 Carriage of damaged EVs

2.6.3.1 Damaged EVs, such as crash-damaged vehicles, may be at a significantly higher risk of catching fire than undamaged vehicles, primarily depending upon whether their battery is damaged.

2.6.3.2 EVs that have been damaged sufficiently to indicate that battery damage might have occurred should be thoroughly inspected by a competent person before being allowed to be transported on board.

2.6.3.3 Where there is suspicion that the battery pack may be damaged then the battery should be removed and carried separately as dangerous good, in accordance with the IMDG Code, SP376, Chapter 3.3.

2.6.4 Charging EVs on board

2.6.4.1 Charging of EVs batteries on board ro-ro passenger ships during the ship's voyage may only be performed from the ship's charging stations, subject to appropriate safety procedures.

2.6.4.2 The owner/driver of the car should notify the carrier of the willingness to charge the car when booking the car transport in order to arrange a suitable stowage place for the car near the charging station.

2.6.4.3 The technical conditions for EVs charging stations as well as safety measures and procedures for charging are given in Chapter 4.

2.6.5 Fire hazards from electric batteries

2.6.5.1 EVs account for an increasing proportion of the means of transport used and are increasingly carried on board ro-ro passenger ferries. Fires in these vehicles do not release significantly more energy than fires of traditionally fueled vehicles and are not at greater risk of fire although such fires may last longer (thus being more dangerous) and be more liable to re-ignite following fire-extinction. There are significant differences in EV fire detection and suppression practices compared to conventional vehicles.

2.6.5.2 Timely response to the first signs of a fire is vital in reducing the risk of a vehicle fire developing and to extinguish it effectively.

2.6.5.3 EVs are most commonly powered by high voltage Lithium-Ion (Li-Ion) batteries. Li-ion battery fires can be "self-sufficient" and continue to burn without access to additional oxygen, they may also continue to generate high amounts of heat following fire-extinction. In hybrid vehicles the risks from both battery and hydrocarbon fires exist simultaneously.

2.6.5.4 The common high-voltage battery consists of lithium-ion cells. These cells are considered dry cells. If damaged, usually only a small amount of clear liquid will leak. The high-voltage battery and drive-unit are liquid-cooled with a typical glycol-based automotive coolant. If this blue coolant is found to leak, the high voltage battery casing may be damaged. Either a blue or clear fluid leak may indicate that the battery is damaged, and such symptoms should prompt the crew to take appropriate preventive action.

2.6.5.5 Thermal-runaway (TR) is the event most associated with catastrophic EVs fires and occurs when the heat generated within a battery exceeds the amount of heat that is dissipated to its surroundings. Internal battery temperature will continue to rise which will cause the battery current to rise; without intervention (such as cooling) this feedback loop continues causing further heat rises and potential fire spread or explosion. The likelihood of this is reduced by modern Li-Ion battery design which allows the battery to vent instead of exploding.

2.6.5.6 Immediately preceding and during TR, gas-freeing occurs – this is a release of various gases from the battery, including carbon dioxide, carbon monoxide, hydrogen, and volatile organic compounds. During the early phase of their generation the off-gases can be heavier than air and accumulate at deck-level or be lighter than air and dissipate, or accumulate at deck-head level. The use of appropriate gas detectors can be helpful in detecting hazards from such dangerous and toxic gases.

2.6.5.7 As well as the above listed gases produced when a Li-Ion battery burns, the following can be released as vapours or particulates in the gases: hydrogen chloride, hydrogen cyanide, soot, oxides of nickel, aluminum, lithium, copper, cobalt, and hydrogen fluoride. It should be noted that most of these gases are also present in traditional vehicle fires, and the same protective measures are required during the firefighting operation. These vapor clouds can be toxic or create an explosion hazard.

2.6.5.8 A damaged high-voltage battery can create rapid heating of the battery cells. If you notice hissing, whistling, or popping, a possible sweet chemical smell, then black "smoke" (nanoparticles of heavy metals, not smoke), then white vapour coming from the high-voltage battery or the vehicle generally, assume that this is battery overheating and appropriate firefighting measures should be taken.

2.6.6 Detection and prevention of EVs fire

2.6.6.1 It is recommended that the closed-circuit television (CCTV) system, mentioned in 2.3.2 be capable of recognizing the flame and rise of temperature.

2.6.6.2 Fire patrols should be trained in the use of thermal imaging cameras. Thermal imaging cameras should be used especially when charging EVs is allowed on board. These cameras can be used to check floor pans of EVs to detect any overheating, before embarking and during voyage. It should be taken into account in determining the alarm temperature that the temperature of the battery is expected to rise during the charging of vehicles. Manufacturers estimate that the minimum temperature in the battery where potential exists for thermal runaway to begin are between 60 °C and 70 °C.

2.6.7 Principles concerning fire extinguishing in EVs

2.6.7.1 It is assumed that activating a fixed water spray system will usually be the most effective first response in the event of an EV fire as it will provide boundary cooling to the vehicle and reduce the likelihood of fire spreading to nearby vehicles.

2.6.7.2 In case of fire involving the Li-Ion batteries, only water supplied in large quantities can cool the batteries. In such cases it is recommended to extinguish manually with fire hoses supplied from the ship's water fire main system, as a fixed water drenching system may not be sufficiently effective due to the limited amounts of water sprayed, although it will help to slow the spread of the fire.

2.6.7.3 As the battery pack being the seat of the most severe EV fires and usually being located on the underside of the vehicle, means to provide cooling-water directly to the vehicle underside should be considered. A nozzle connected to a fire hose with an upward pointing spray, which could be placed under a vehicle, can be an effective means to provide this direct cooling water effect. Fixed water monitors may be used to provide boundary cooling to allow firefighting teams to carry out other activities. Traditionally fueled vehicles are assumed to require around 4,000 liters of water to suppress a fire, while EVs can require around 10,000 liters, depending on battery size and application method.

2.6.7.4 Water mist lances are specialized devices of equipment which can deliver water directly into the inside of the battery by piercing the casings and provide direct cooling to the cells by supplying water inside the battery enclosure. However, an incompetent use of these devices may damage the battery even more and thus provoke further ignition. The use of the lance should be carefully considered with regard to the risks from penetrating the battery enclosure and it is recommended that their use be reserved for firefighting professionals.

2.6.7.5 To control and suppress fires in EVs, it may be necessary to use specialized fire-fighting equipment, such as foam fire extinguishers, car fire blankets, water mist lances or water monitors on open decks. Such firefighting equipment should be readily accessible for use, close to the access points to vehicles.

2.6.7.6 Other methods to restrict the flame and heat spread such as specialist car fire blankets or other specialist textile boundaries may be used until sufficient water quantity is available. The use of fire blankets and other specialist textile boundaries should be considered bearing in mind the limited access around vehicles on the car deck and the risk to the crew from deploying a fire blanket. Such fire blankets/ textile boundaries may be best suited as a precautionary measure when a vehicle has been identified as being exposed to an increased risk of fire. While vehicle fire blankets/ textile boundaries will contain flame, the TR event will continue, and this may generate vapour clouds that contain an explosive gas mix.

2.6.7.7 A fire team involved in firefighting activities should be aware of the difference between white pre-ignition vapour clouds and grey/black post ignition smoke to determine if the battery is in pre-ignition TR or if this is a developed fire. Due to the risk of side venting of the batteries to avoid explosion crew involved in firefighting activities should maintain an appropriate distance from the vehicle while applying fire suppression mediums.

2.6.7.8 Personnel who are to undertake fire-fighting in EVs must be aware of the dangers posed by high voltage electrical equipment in EVs. It is essential to ensure, as part of the firefighting procedure, that the power supply from the ship's electrical system to each vehicle being charged is cut/ isolated prior to attempting to extinguish the fire. Where the EV is isolated/ isolated from the ship's electrical supply (i.e. not being charged), the risk of electric shock when extinguishing an EV fire is very low.

2.6.7.9 After the EV fire has been successfully extinguished, the risk is that the vehicle will reignite. Such a vehicle should be monitored by the crew, ready to undertake additional firefighting measures until the vehicle is removed from the ship.

2.6.7.10 Firefighters should always use full personal protective equipment during a firefighting operation, including self-contained breathing apparatus (SCBA), which should be worn whenever there is a risk of exposure to smoke from a fire in the EV battery. During a firefighting action on board the ship, appropriate measures should be taken to protect the crew and passengers, using the ship's position "downwind" in relation to the site of the fire incident. Where possible, muster stations for passengers and crew that are not exposed to smoke should be used.

2.6.7.11 Procedures should be developed for decontamination of firefighters and handling of contaminated clothes and equipment after any firefighting operation where there was exposure to smoke from an EV. The smoke produced by a burning EV may contain hydrogen fluoride, a hazardous substance that may penetrate protective clothing. It is highly corrosive and toxic and will cause chemical burns if it permeates through clothing and comes in to contact with skin. As such the procedures for dealing with clothing and equipment exposed to battery fires may be more onerous than those exposed to traditional vehicle fires.

2.6.7.12 Any specialized response to EV fires should be included in the established fire drills for ships.

2.6.8 Delivering of water from fire hoses

2.6.8.1 In the case of the transport of EVs, bearing in mind that a large amount of water is required to fight fires and cool electric batteries, and the intensity of water supply from a fixed water drencher system is insufficient (usually 5 to 15 l/ min/ m^2 and covers the entire section), in the vicinity of the EV parking area, there should be 2 hydrants required by SOLAS, reg. II-2/10, enabling the application of 2 jets of water to a burning electric car. It may be expedient and effective to feed water from hoses from the bottom of the car directly to the battery located under the car.

2.6.8.2 During the transport of vehicles, permanent access to these hydrants shall be ensured, enabling firefighters to extend fire hoses and apply water to each of the transported EVs, as well as to adjacent vehicles, for cooling them. If flat hoses are used on the ship, the access route to the hydrants should be straight, allowing the hose to be unrolled along its entire length, otherwise semi-rigid hoses wound on a drum and permanently connected to the hydrants should be used.

3 APPLICATION TO RO-RO CARGO SHIPS AND PURE CAR CARRIERS (PCC) (PCTC)

3.1 Stability checks and loading limitations

EVs are assumed to be on average 25% heavier than similarly sized conventional vehicles and have a lower-positioned center of gravity. When loading EVs, this should be taken into account when calculating the load and stability of the ship.

3.2 Precautions against ignition

3.2.1 Identification of vehicles

Prior to the commencement of loading of vehicles, the shipper should provide the ship's operator with information about the type of fuel or energy supply of the transported AFVs, specifying the type of vehicle.

The ship's crew should be aware of the location on board of the type of AFVs (according to the stowage plan) and should be able to quickly identify the type of AFV from the information provided.

3.2.2 Conditions for carriage

AFVs should only be allowed onboard if they comply with the provisions of the IMDG Code as also described in1.4.3. Particular attention should be paid to the following:

- **.1** if there is suspicion that the EV is damaged or its battery is defective, they should only be allowed transported on a trailer if their battery is removed;
- **.2** the vehicles are free from any leakages of fuel/gases.

EVs powered solely by a battery (BEV) shall not be admitted on board when the battery charge level is below the minimum level ensuring proper operation of the vehicle, allowing self-propelled entry and exit, as specified in 3.2.3.

3.2.3 State of charge (SoC) of EVs batteries

3.2.3.1 Although the battery state of charge (SoC) does not affect the total energy released from a battery fire, it does have a direct effect on the growth and peak heat release rate, which means that batteries with a higher charge level will tend to release heat at higher heat peaks and much faster than batteries with a lower charge level.

3.2.3.2 The state of charge of the battery is also associated with the occurrence of TR, which means that lower values significantly reduce the likelihood of TR. Note that a battery charge <30% means that TR is very unlikely to occur. This refers to the actual state of charge of the battery, which is rarely the same as the state of charge displayed on the vehicle.

3.2.3.3 Taking the above assumptions into account, particular attention should be paid to the maximum battery charge levels recommended by car manufacturers when charging EVs. Note that these may vary depending on the car manufacturer, car model and distance to the destination.

3.2.3.4 As a general rule, EVs should display the battery charge status values in the appropriate 20% to 50% charge range. Vehicles that can be put into "transport mode" that operate in "off" mode throughout the logistic chain must have sufficient battery power to safely operate the basic functions of the vehicle. All ICE-powered hybrid vehicles with electric mode off should do so during transport.

3.2.3.5 For EVs powered only by battery (BEV), a lower battery charge limit of approximately 20% is recommended in order to ensure a minimum basic driving and vehicle service time, including port time, loading and unloading operations, to the first point of destination. For vehicles with a smaller battery capacity, a higher battery limit of approx. 50% is recommended to ensure that the vehicle runs from the factory distribution line to the final unloading port.

3.2.4 Low ground clearance for EVs

EVs batteries are usually placed under the vehicle between the two axles. Low ground clearance vehicles should be clearly marked by their manufacturers to draw attention to vehicles with low ground clearance batteries that can lead to gradeability and elevation angles on ship ramps and internal driveways.

Ship operators may request advance notification of low clearance units with information specifying the vehicle gradeability and angle of change for such EVs. Vehicle manufacturers should consider using spring blocks or other suspension movement control methods on low ground clearance vehicles or under battery plate covers as a measure to prevent damage to low ground clearance vehicles.

Ship operators can take all precautionary measures to avoid ground contact and damage to the batteries.

3.2.5 On board charging of EVs

Charging EVs on board ro-ro cargo ships / car carriers should not be allowed. On-board charging may only be allowed when the EV with a discharged battery needs to be moved to allow other vehicles to be unloaded. In such case, loading should be performed by shippers after obtaining the consent of the First Officer of the ship.

Electrical plugs, charging devices and cables should be carefully checked before use. Only approved equipment should be used for charging.

3.3 Fire detection and extinguishing

When transporting different types of AFVs, the rules and procedures set out in Chapter 2 apply accordingly.

4 TECHNICAL CONDITIONS FOR CHARGING ON BOARD OF ELECTRIC VEHICLES

4.1 Charging stations of EVs

The charging stations should be located in an area where the impact of a possible fire in the EV being charged on other vehicles is minimal.

The electrical installation of the charging station should meet the applicable requirements of IEC 61851-1 - Electric vehicle conductive charging system.

4.1.1 Design documentation

Design documentation for an on-board vehicle charging stations should include the following items:

.1 Description and design assumptions of the station;
.2 Energy balance taking into account the number and power of stations, allowing for simultaneous charging of vehicles;
.3 Risk analysis;
.4 Arrangement and attachment of the charging stations;
.5 Technical documentation of charging stations electrical systems, including an isolating transformer;
.6 Certificates or test reports confirming the suitability of using charging station components/ devices in marine conditions;
.7 Specification of electric cables;
.8 Monitoring and alarm system of operation parameters for the stations;
.9 Diagram of remote emergency shutdown of the charging stations;
.10 Diagram of the arrangement of monitoring points for vehicle loading stations;
.11 Arrangement plan of fire extinguishing measures.

4.1.2 Operational documentation

Documentation for the safe operation and maintenance of the recharging stations should be available on board, including:

.1 design documentation of the station;
.2 crew procedures during charging of vehicles;
.3 maintenance plan for the charging stations.

4.1.3 Electrical systems of the charging station

.1 Electrical protection class:

The onshore charging stations are rated IP 54 in accordance with the industry standard. For use on board, electrical installations require protection class IP 55 - indoors or IP 56 - on open decks to ensure adequate protection against water splashes. In addition, the charging station should be resistant to the influence of the environment with a saline atmosphere, which should be confirmed by appropriate environmental tests (see paragraphs 2.5 to 2.7, 2.10 and 2.11 of Publication 11/P).

.2 Explosion protection:

In the case of stations located below deck, bearing in mind the possibility of an explosive atmosphere in vehicle spaces, the station with the charging cable should be installed at a height greater than 450 mm from the deck. Otherwise, it should have an appropriate Ex protection degree.

.3 Vibration:

The charging station should be designed to have at least the vibration resistance required for all other electrical installations on board (see paragraph 2.8 of Publication 11/P).

.4 Inclined positions:

The charging station should be so designed that no unintentional switching operations or functional changes may occur at electrical or electronic devices on board up to an angle of inclination of 22.5° to each side. (see paragraph 2.9 of Publication 11/P).

.5 Electromagnetic Compatibility:

The electrical installation of the station should be resistant to interference from other electrical devices in its vicinity. In order to protect against the influence on ship installations, the charging station should not emit electromagnetic, radiated and conducted disturbances (see paragraphs 2.15-2.21 of Publication 11/P).

.6 Voltage and frequency deviations:

All electrical equipment on board must be designed to function without interference from voltage and frequency variations during normal operation.

Permissible deviations for DC and AC systems are specified in paragraph 2.1.3.1, Part VIII of the *Rules for the Classification and Construction of Sea-going Ships*.

.7 Network parameters:

While the transmission voltage onshore is typically 400 V and 50 Hz, most ships operate at 440 V and 60 Hz. The charging station should be able to function according to these input values. This is especially important if the voltage and frequency conversion is done in the charging station and not in the car.

.8 Power grid earthing:

The earthing of the network should be established by means of an isolating transformer. The transformer should be adapted to the performance parameters of the charging station.

.9 Power cable:

The cable with a plug for connecting the car to be charged should be permanently connected to the charging station in such a way that no driver of the vehicle can use his own cables.

.10 Integration into the onboard Power Management System:

The charging station should be integrated with the ship's Energy Management System. Integration in the group of "minor receivers" is recommended. Should the vessel require an increase in power, the charging station may be automatically disconnected from the grid until sufficient power is available again.

.11 Manual switch-off:

It shall be possible to easily disconnect the entire charging station from the mains in order to stop any further charging, e.g. by manual switch-off (only available to the crew). This may be necessary, for example, if dangerous goods are being transported near the station or if severe weather conditions are expected. The disconnecting device (to disconnect the charging station from the power supply) should be located in a safe, non-explosive area/ room. If required, this can also be realized through integration with an Energy Management System.

4.1.4 Safety and monitoring measures of the station

.1 Integrated protection features:

The charging station on board must have all the safety measures that are also required ashore. Among other things, it is required to provide communication functionality between the charging station and the vehicle's battery management system, such as.

- short circuit protection;
- overcharge protection - turns off when the battery is overcharged;
- internal cooling of the charging station or charging cable if required (depending on the power);
- temperature monitoring of the charging station, cable and plug – shutdown in the case of damage and overheating;
- shutdown in the event of a vehicle battery management system risk warning.

.2 Integration into ship´s Alarm and Monitoring System:

The charging station should generate an alarm in the event of internal and external failures. The alarm should be sent to the bridge or to a continuously manned central command post (e.g. engine room maneuvering and control room).

.3 Ventilation:

There should be an adequate operation of the ventilation system in the vicinity of the charging station for use in normal conditions and emergency situations.

.4 Remote emergency shutdown:

In an emergency, e.g. a fire in the vicinity of the charging station, it should be possible to switch off the charging station manually.

.5 Alarm:

Each charging station shall give an audible and visual alarm distinct from the other alarms in the ro-ro cargo space in the event of a hazardous situation (e.g. problem at the charging station, with the connection or with the car battery).

.6 Monitoring:

A video surveillance system that fully covers the charging station and its surroundings should be provided. Thermal imaging should be preferred. The recording should be available and grouped together with other fire control equipment and systems in a continuously manned control post or in the security center where provided.

.7 Mechanical protection of components and cables:

IK10 protection should be considered. In addition, any components of the charging station that can be installed outside of the ro-ro cargo space should be installed elsewhere.

.8 Fire detection:

There should be fire detectors in the area of the charging station.

4.1.5 Signage and marking of charging station

Charging stations should be clearly marked with appropriate signs and designated car charging points should be painted on the car deck of the vessel. Warning notices should be posted at each charging station to prohibit passengers from starting / stopping any charging activities without the presence of the ship's crew.

4.1.6 Certificates and documents of compliance

Charging station equipment and components should be delivered with appropriate certificates and/or documents of compliance for use in marine conditions.

4.1.7 Operation tests of the charging station

After being installed on board, EVs charging stations and their parameter monitoring and alarm systems should be subjected to functional tests in accordance with the program of final acceptance and tests.

4.2 Electrical connections to the charging station

4.2.1 Electric cables permanently connected to the charging station should be long enough to reach the socket of the vehicle to be charged without creating a hazard to passengers moving around the car deck and not to allow the cable itself to be stretched. In the event that the cable becomes tense (e.g. as a result of vehicle movement in bad weather), the connection to the car socket should be disconnected (emergency disconnection). The use of cable extensions with a plug is not recommended.

4.2.2 Electric cables for connecting the vehicle to the charging station, which may be damaged during loading by other vehicles during loading and unloading, should be adequately secured, even when armored, unless the ship's structure or other arrangements, such as suspending cables underneath the ceiling, provide adequate protection. All cabling should be adequately protected against corrosion and effectively earthed.

4.2.3 Unused electric cables for connecting the vehicle to the charging station shall be stored in a way that prevents their damage during loading / unloading operations.

4.3 Crew procedures for charging of EVs

Procedures for crew during charging of vehicle should be developed for each ship, containing the following information:

- **.1** converted/ modified EVs, other than the factory-made ones, cannot be accepted for on-board charging;
- **.2** only properly trained personnel or other persons under the supervision of the ship's crew may connect and disconnect EVs during charging;
- **.3** electric cables of EVs charging stations, together with the plug, should be checked for their technical condition by trained personnel before connecting to the vehicle;
- **.4** before plugging/ unplugging the charging cable, it is usually required to press the unlock button on the car/ car key to physically unlock the car's charging connector. This ensures that when connecting/ disconnecting the cable, there is no electricity on the car-cable-charging station connection. This means that the driver of the car must be present when plugging/ unplugging the charging cable. The ship's procedures should include information on the method of notifying the car driver during the ship's journey by the crew (e.g. by sending an SMS) about the commencement/ completion of loading the vehicle and calling the driver to enter the vehicle space with the assistance of a crew member;
- **.5** the use of cables other than the ship's cables is prohibited when charging of EVs.

4.4 Procedure for fire extinguishing

The emergency response procedure, required in par. 2.4.1.1, should include information that the charging process should be interrupted and the charging station disconnected from the power supply before start of extinguishing the fire.

4.5 Maintenance plan

The ship should have a maintenance plan for charging stations and electric cables and related equipment used in ro-ro/ special category spaces for charging EVs.

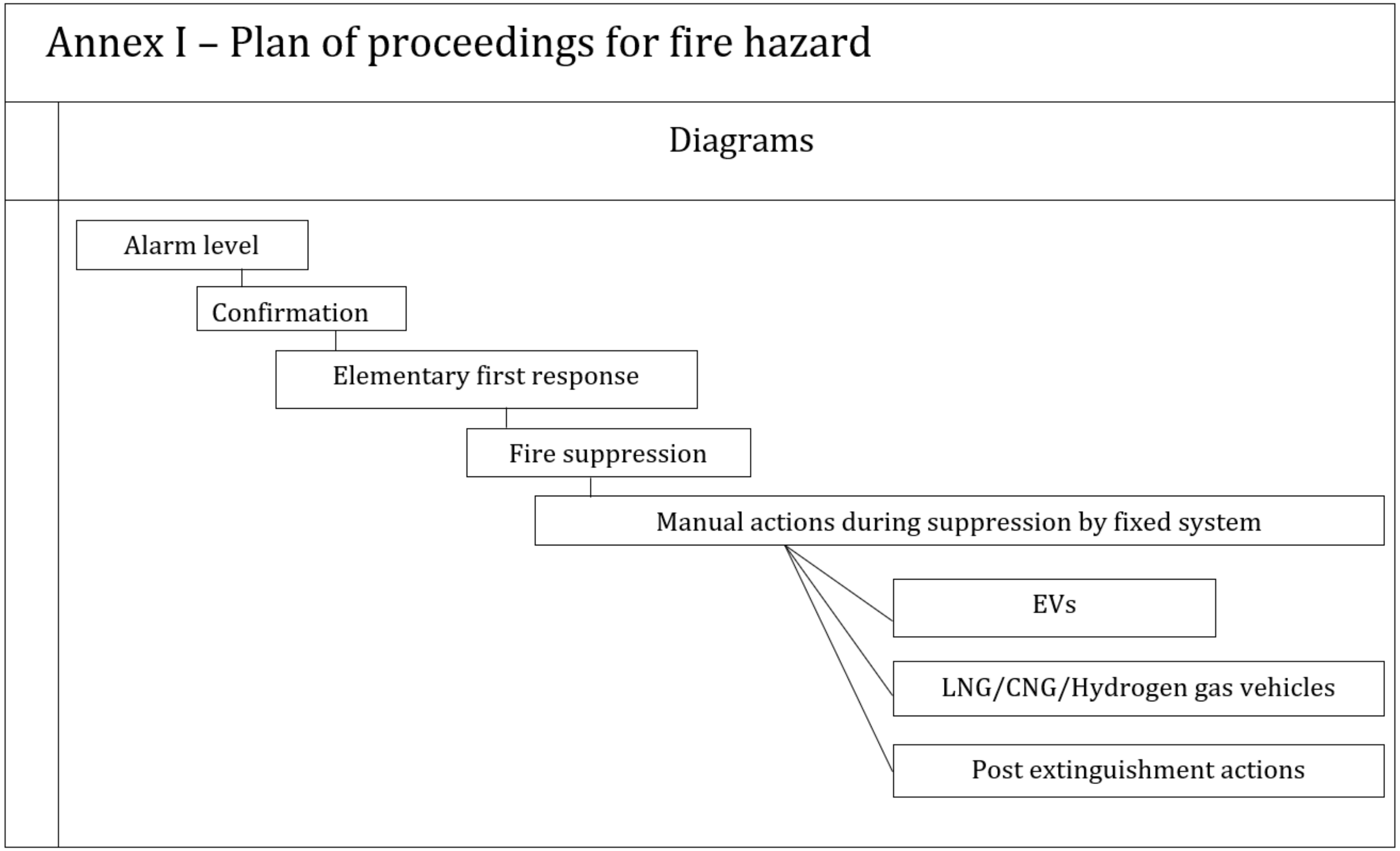
List of source documents:

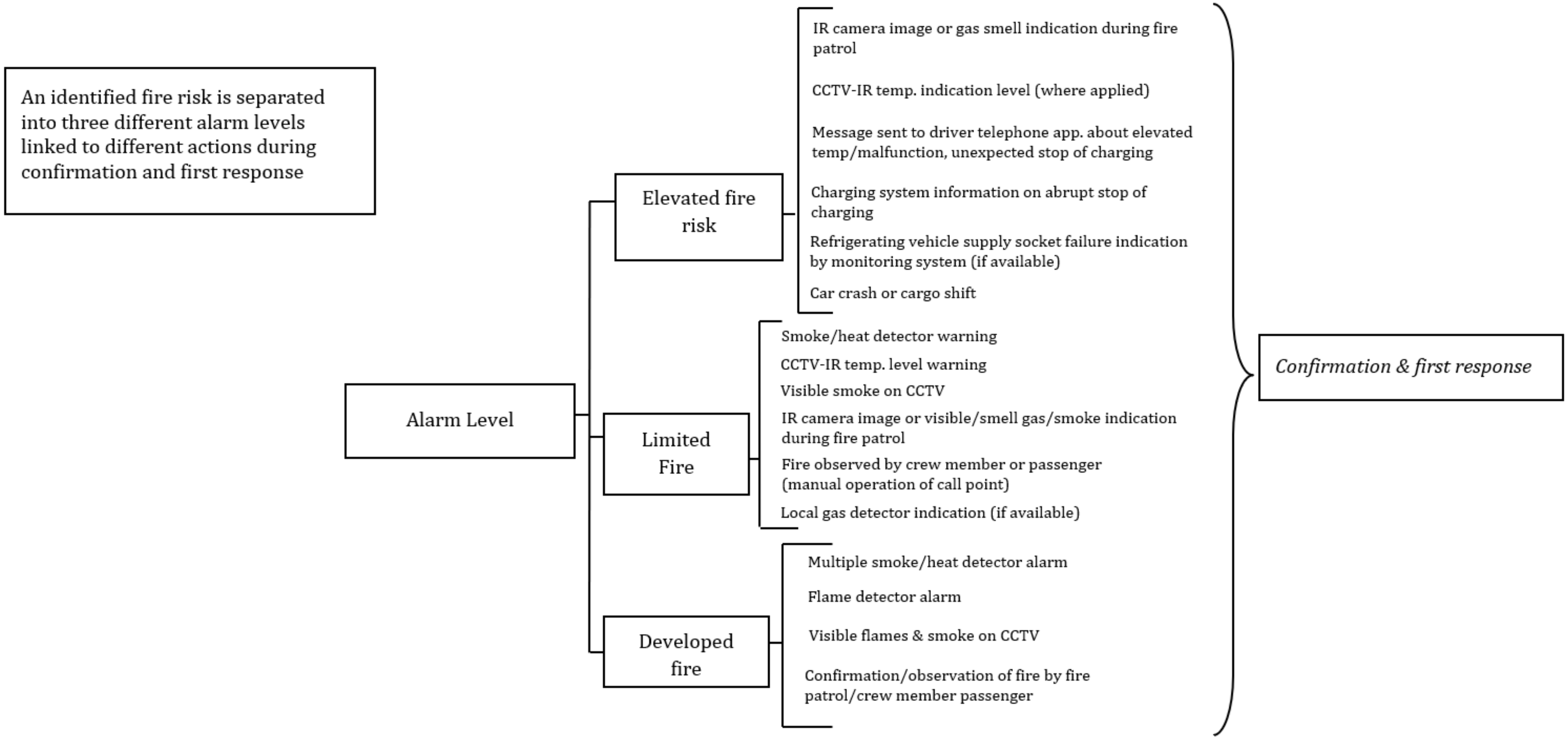
1. Risk assessment as required by the IGF Code – IACS Rec. No. 146.
2. Risks associated with alternative fuels in road tunnels and underground garages – SP Technical Research Institute of Sweden.
3. Catalog of requirements for the layout of charging stations onboard of ro-ro-ferries, Work Package 5.4 – ALBERO Project.
4. UECC Electric Vehicle Guideline – United European Car Carriers.
5. Technical Reference for Li-ion Battery Explosion Risk and Fire Suppression – DNV GL Report No. 2019-1025, Rev. 4.
6. Fire test research on ships carrying lithium-ion battery vehicles – IMO, SSE 7/INF.11.
7. Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships – MSC.1/Circ.1615.
8. Guidance for the safe carriage of alternative fuel vehicles (AFVs) in ro-ro spaces of cargo and passenger ships, Version final 1.1. – EMSA.
9. BREND 2.0 – Fighting fires in new energy carriers on deck 2.0 – RISE Report 2022:47.
10. International Maritime Dangerous Goods (IMDG) Code, Special Provisions 961 and 962.
11. Second study investigating cost-efficient measures for reducing the risk from fires on ro-ro passenger ships — Combined Assessment, EMSA (FIRESAFE II), 12/2018.
12. Electric vehicles onboard passenger roll-on/roll-off (ro-ro) ferries – MGN 653 (M) – Maritime & Coastguard Agency, Published 21 July 2022.

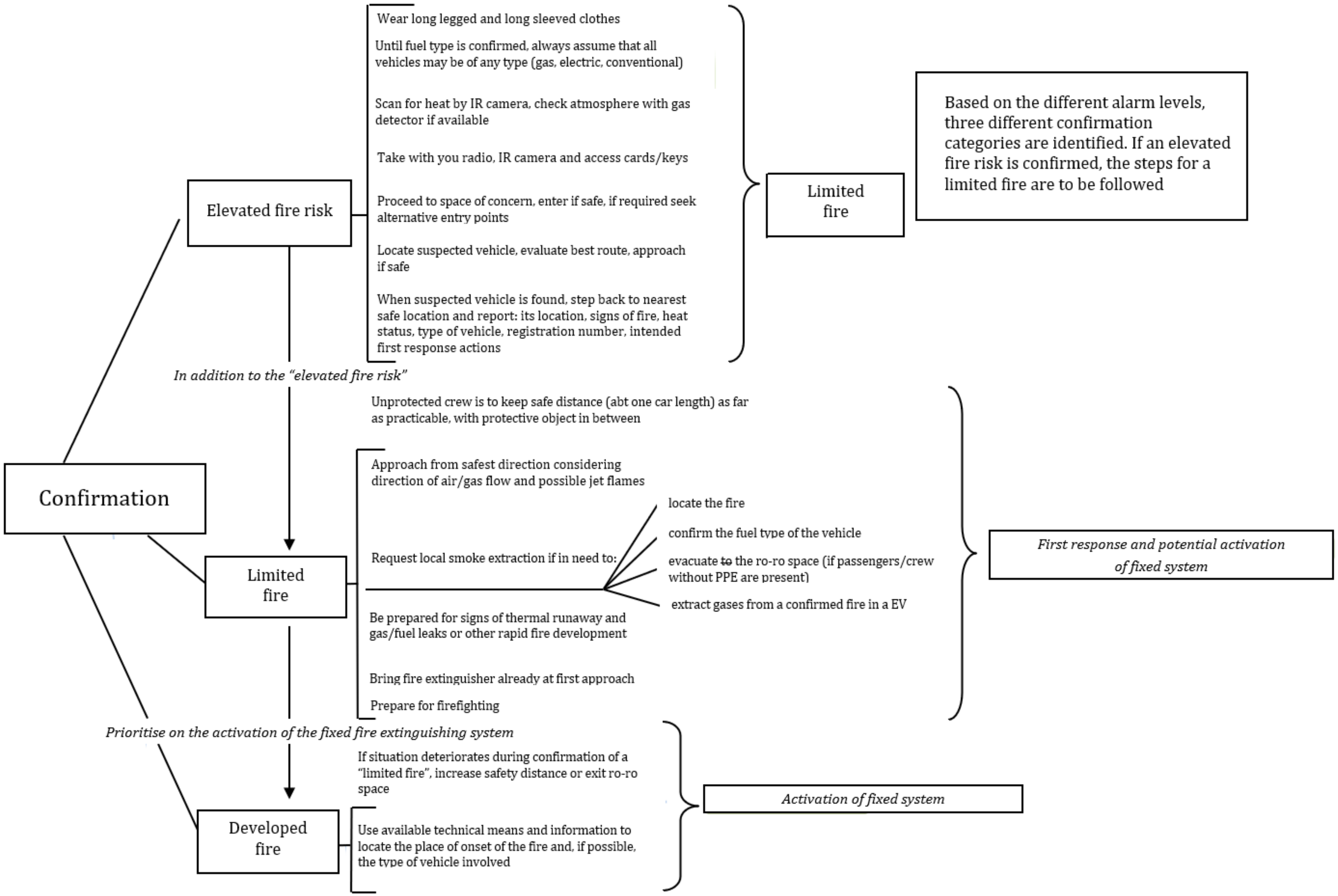
Annexes

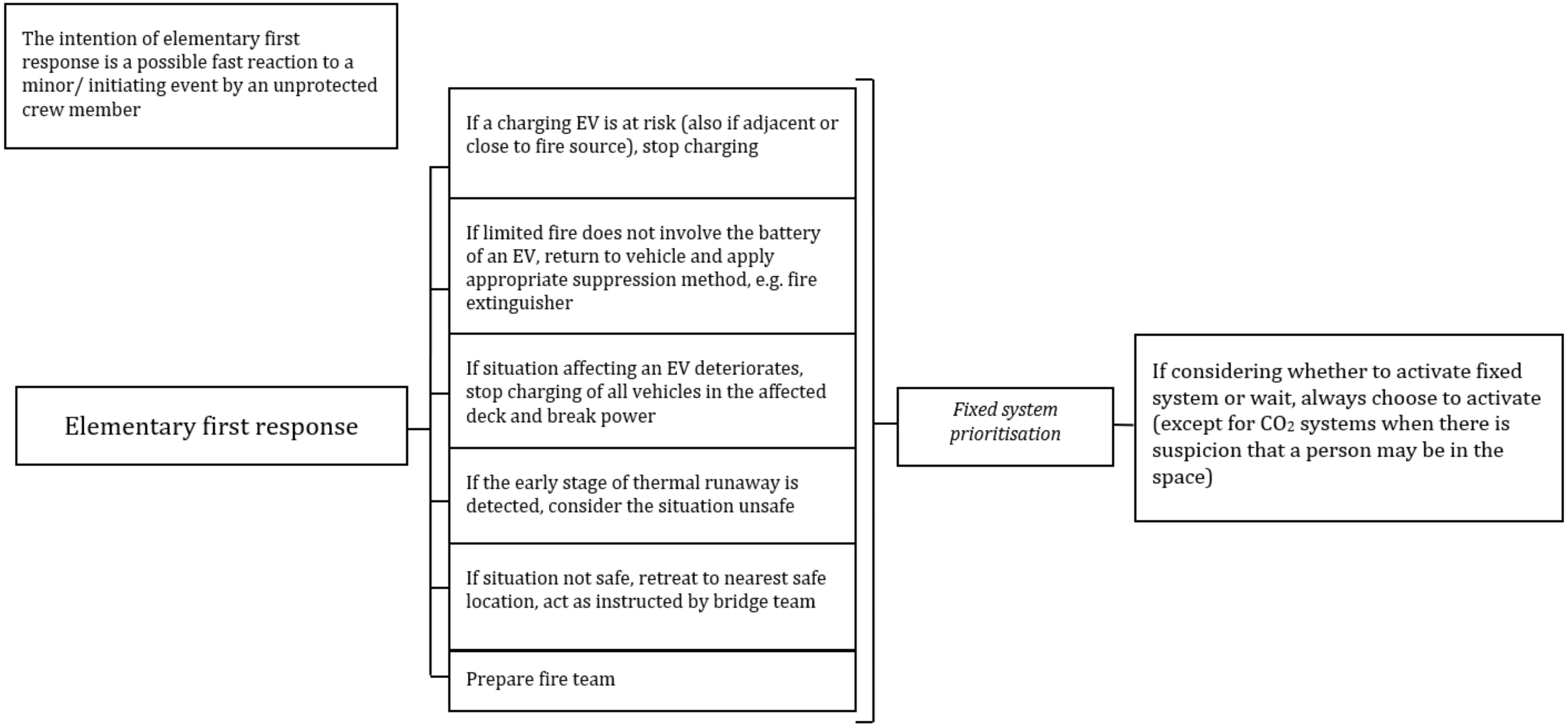
I. Operational guidance in case of AFVs fire incidents

The purpose of this annex is to guide operators and crew on how to act in the risk of fire considering conventional vehicles and AFVs in a safe and effective way.




An identified fire risk is separated into three different alarm levels linked to different actions during confirmation and first response
Alarm Level
Elevated fire risk
IR camera image or gas smell indication during fire patrol
CCTV-IR temp. indication level (where applied)
Message sent to driver telephone app. about elevated temp/malfunction, unexpected stop of charging
Charging system information on abrupt stop of charging
Refrigerating vehicle supply socket failure indication by monitoring system (if available)
Car crash or cargo shift
Limited Fire
Smoke/heat detector warning
CCTV-IR temp. level warning
Visible smoke on CCTV
IR camera image or visible/smell gas/smoke indication during fire patrol
Fire observed by crew member or passenger (manual operation of call point)
Local gas detector indication (if available)
Developed fire
Multiple smoke/heat detector alarm
Flame detector alarm
Visible flames & smoke on CCTV
Confirmation/observation of fire by fire patrol/crew member passenger
Confirmation & first response


Confirmation
Elevated fire risk
Wear long legged and long sleeved clothes
Until fuel type is confirmed, always assume that all vehicles may be of any type (gas, electric, conventional)
Scan for heat by IR camera, check atmosphere with gas detector if available
Take with you radio, IR camera and access cards/keys
Proceed to space of concern, enter if safe, if required seek alternative entry points
Locate suspected vehicle, evaluate best route, approach if safe
When suspected vehicle is found, step back to nearest safe location and report: its location, signs of fire, heat status, type of vehicle, registration number, intended first response actions
Limited fire
Based on the different alarm levels, three different confirmation categories are identified. If an elevated fire risk is confirmed, the steps for a limited fire are to be followed
In addition to the "elevated fire risk"
Unprotected crew is to keep safe distance (abt one car length) as far as practicable, with protective object in between
Limited fire
Approach from safest direction considering direction of air/gas flow and possible jet flames
Request local smoke extraction if in need to:
locate the fire
confirm the fuel type of the vehicle
evacuate ~~to~~ the ro-ro space (if passengers/crew without PPE are present)
extract gases from a confirmed fire in a EV
Be prepared for signs of thermal runaway and gas/fuel leaks or other rapid fire development
Bring fire extinguisher already at first approach
Prepare for firefighting
First response and potential activation of fixed system
Prioritise on the activation of the fixed fire extinguishing system
Developed fire
If situation deteriorates during confirmation of a "limited fire", increase safety distance or exit ro-ro space
Use available technical means and information to locate the place of onset of the fire and, if possible, the type of vehicle involved
Activation of fixed system


The intention of elementary first response is a possible fast reaction to a minor/ initiating event by an unprotected crew member
Elementary first response
If a charging EV is at risk (also if adjacent or close to fire source), stop charging
If limited fire does not involve the battery of an EV, return to vehicle and apply appropriate suppression method, e.g. fire extinguisher
If situation affecting an EV deteriorates, stop charging of all vehicles in the affected deck and break power
If the early stage of thermal runaway is detected, consider the situation unsafe
If situation not safe, retreat to nearest safe location, act as instructed by bridge team
Prepare fire team
Fixed system prioritisation
If considering whether to activate fixed system or wait, always choose to activate (except for CO_2 systems when there is suspicion that a person may be in the space)

Fire suppression as presented here should be understood as being generic and applicable to all vehicle types

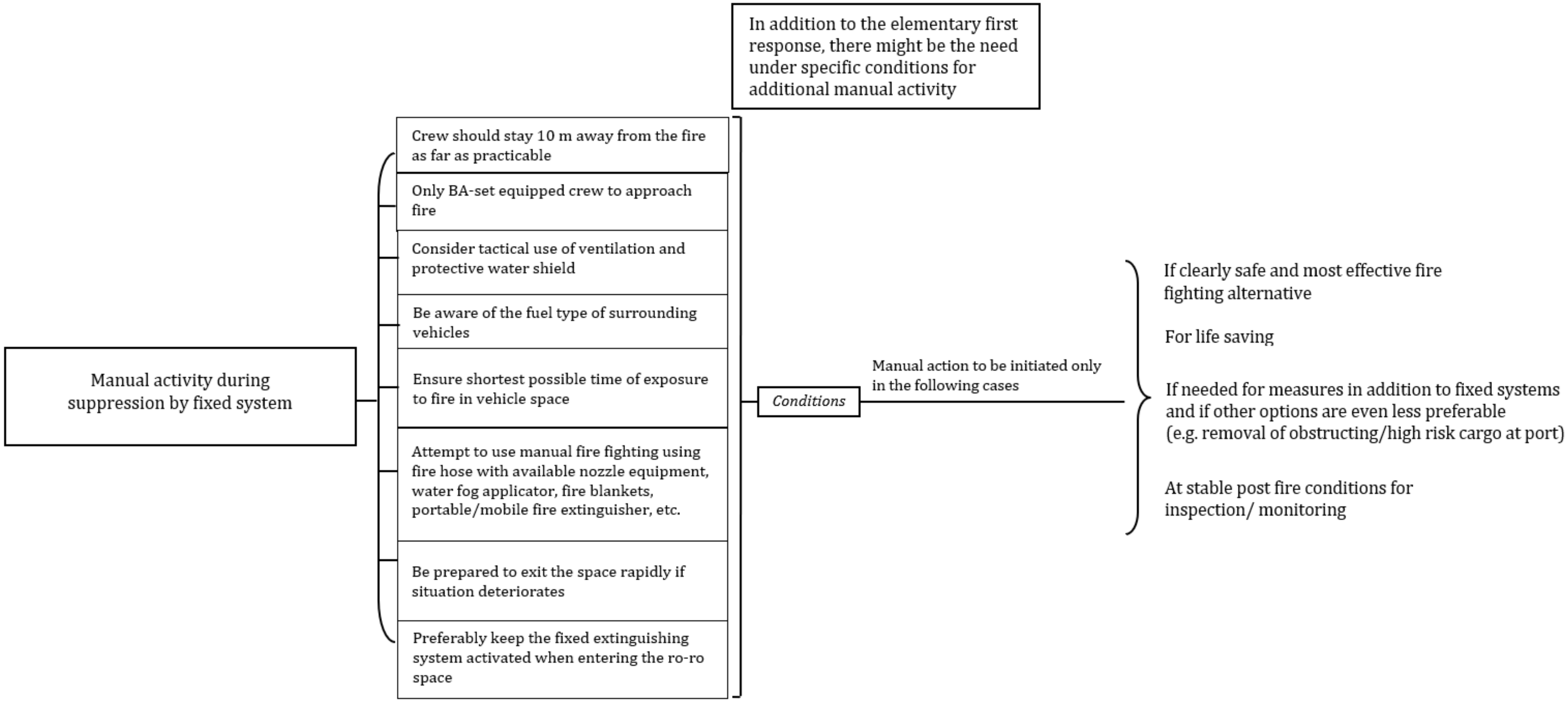
Fire suppression – All vehicle types

Main actions

- Activate fixed system
- Mobilize fire team
- Put ventilation/fire dampers in suitable fire mode
  - Normal operation -> get potential gases out 6/10 ACPH
  - Elevated risk, gas emission, pre fire -> gas evacuation
  - Fire -> Minimize oxygen supply
  - Manual entry -> secure fresh air
- Apply boundary walls cooling as required
- Monitor fire development taking into account cargo type and location, stability, temperature of boundaries, smoke and gas conditions
- If significant signs of improvement are observed (significant drop in temperature of boundaries of adjace spaces for a period of at least 1 h) calibrate strategy
- If significant signs of deterioration and uncontrolled fire growth are observed (e.g. fire spread on a second deck), ship evacuation should be considered taking into account smoke/fire conditions

General principles

- Use primarily remotely controlled systems such as (IR-cameras), CCTV, heat detectors, sprinklers, water monitors
- Do not enter vehicle space unless for lifesaving or similarly urgent conditions
- Unprotected crew to stay out of ro-ro spaces
- On weather decks
  - Use fixed system if available
  - If fixed system is unavailable, take appropriate measures to protect crew and accommodation areas from heat/smoke/possible explosions
  - Manual means only to be used as a first response, for cooling or for lifesaving taking weather conditions into consideration


In addition to the elementary first response, there might be the need under specific conditions for additional manual activity
Manual activity during suppression by fixed system
Crew should stay 10 m away from the fire as far as practicable
Only BA-set equipped crew to approach fire
Consider tactical use of ventilation and protective water shield
Be aware of the fuel type of surrounding vehicles
Ensure shortest possible time of exposure to fire in vehicle space
Attempt to use manual fire fighting using fire hose with available nozzle equipment, water fog applicator, fire blankets, portable/mobile fire extinguisher, etc.
Be prepared to exit the space rapidly if situation deteriorates
Preferably keep the fixed extinguishing system activated when entering the ro-ro space
Conditions
Manual action to be initiated only in the following cases
If clearly safe and most effective fire fighting alternative
For life saving
If needed for measures in addition to fixed systems and if other options are even less preferable (e.g. removal of obstructing/high risk cargo at port)
At stable post fire conditions for inspection/ monitoring

Additional considerations related to manual activity during fire suppression

EVs

Before approaching

- If vehicle charging or reefers supply are connected to the ship electrical system, stop charging and break power
- Fire suits and PPE must be worn according to instruction with sealed gaps and an inner second layer

Approach

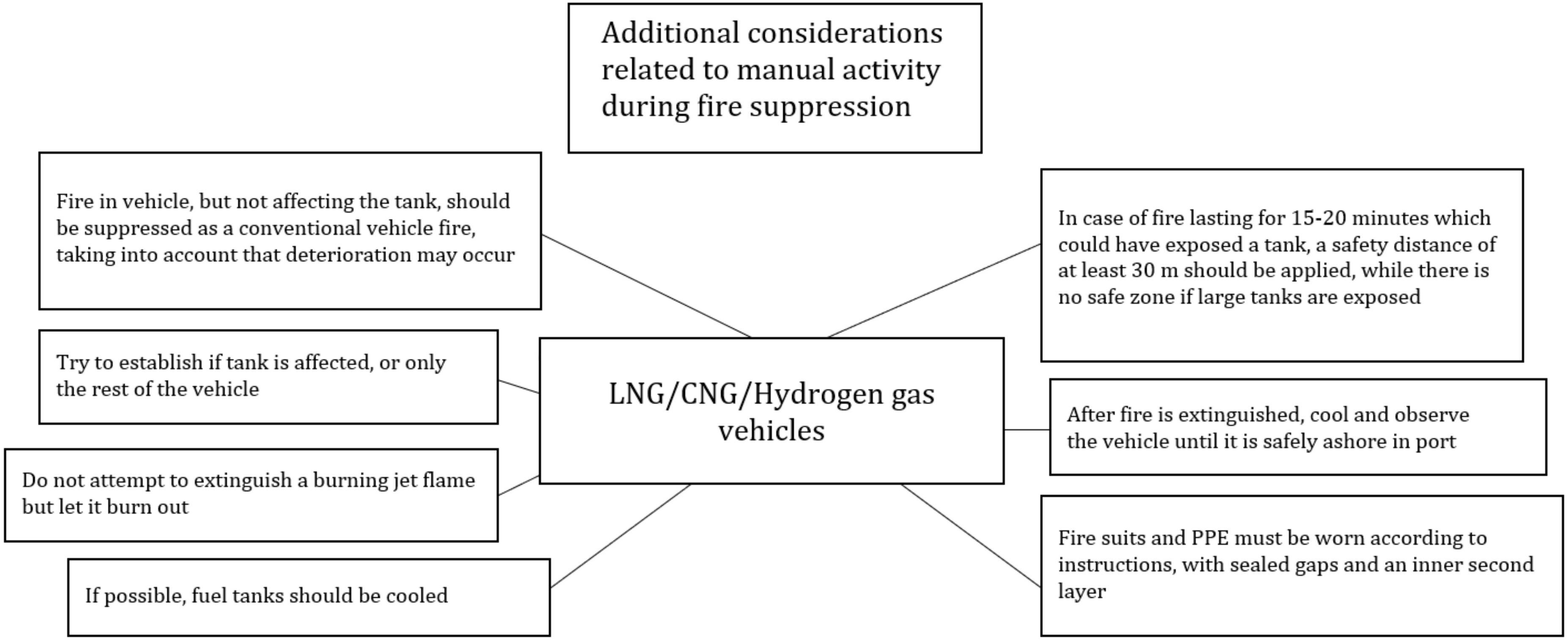
- Try to establish if battery is in fire or only the rest of the EV
- Approach from safest direction considering direction of gas/smoke flow and possible jet flames. If flames/smoke get out of battery, apply safe distance
- Max smoke-gas exposure time 40 minutes, no re-entry into the room is possible. Be aware that burning Li-Ion batteries may emit high quantities of toxic HF

Extinguishing

- Consider vehicle specific battery configuration before penetrating vehicle and do not pierce the bonnet
- Fire in EV, but not affecting the battery, should be suppressed as a conventional fire, taking into account that a rapid deterioration may occur
- Do not attempt to extinguish a burning jet flame. Allow any jet flame to burn out. Consider the risk of low jet flames from the batteries

Cooling

- If possible, cool the traction battery, remote manual hose could be applicable until cooling device is in place
- If possible cool the surrounding vehicles to avoid fire spread
- After fire is extinguished, cool and observe car/battery temperature until safely ashore in port


Additional considerations related to manual activity during fire suppression
LNG/CNG/Hydrogen gas vehicles
Fire in vehicle, but not affecting the tank, should be suppressed as a conventional vehicle fire, taking into account that deterioration may occur
Try to establish if tank is affected, or only the rest of the vehicle
Do not attempt to extinguish a burning jet flame but let it burn out
If possible, fuel tanks should be cooled
In case of fire lasting for 15-20 minutes which could have exposed a tank, a safety distance of at least 30 m should be applied, while there is no safe zone if large tanks are exposed
After fire is extinguished, cool and observe the vehicle until it is safely ashore in port
Fire suits and PPE must be worn according to instructions, with sealed gaps and an inner second layer

Generic post extinguishment measures

Post-extinguishment

EVs

- A Li-ion battery may emit gas and/or flames at any time if not fully burnt out
- Symptoms of exposure to HF may not be immediately evident. If in doubt, medical treatment should be sought immediately
- Monitor temperature on batteries of EVs subjected to fire until they are unloaded

Decontamination

- After the completion of their task, firemen staying in smoke should take a shower and after rest in fresh air if possible
- Consider used fire fighting and protective gear as hazardous/ contaminated material. Handling of used equipment – only with protective gloves and in the place as close to the fire exposed space as possible

Gas supplied vehicles

- Monitor cryogenic gas storage tanks (LNG, LH_2); in case insulation is lost (boil-off risk), external frost might be visible
- Allow fire exposed gas tanks to cool down before the vehicle is approached
- Gas tanks will regain their strength, but composite material may leak – use nose/ smell, noise/hearing or a gas detector to verify
- While minor leakages should not be an issue in large spaces as roro-spaces, full air replacement/ gas extraction should be performed
- Apply local cooling or other boundary cooling method as precautionary measure

II. General fire properties of AFV vehicles

The purpose of this annex is to provide some basic characteristics and properties of different types of AFVs in an overview format, in order to be able to rapidly communicate differences between different types of vehicle fires.

Parameter	Cab fire	ICE	HEV	EV	LNG/LPG/CNG	Hydrogen	Small electric units
Energy carrier	Plastic material, rubber, textile etc	Petrol, Diesel	NiCd/Li-Ion battery & Petrol	Li-Ion battery	Liquified CH_4/ Liquified Butane & Propane/ Compressed CH4	Compressed H_2	Li-Ion battery
Gas form density relative air	N/A	N/A	N/A	Heavier apart from H_2	Lighter/ Heavier/ Lighter	Lighter	Heavier apart from H_2
Toxicity (pre-fire)	N/A	N/A	N/A	Yes	Asphyxiant	Asphyxiant	Yes
Stowage advice	No preference	No preference	No preference	No preference	Preferably weather and, alternatively, open decks	Preferably weather and, alternatively, open decks	Designated area on vehicle deck, if possible, with natural ventilation
Pre-ignition signs of increased fire risk	Smoke, heat	Fuel leak	Fuel leak	Heavy smoke & heat from battery. Popping sounds from battery cells	Noise from Pressure Relief Device.	Noise from Thermally activated Pressure Relief Device	Heavy smoke & heat from battery. Popping sounds from battery cells
Ignition	Heat/ spark and external fire	Heat/ spark and external fire	Heat/ spark and external fire	Battery heat, external heat/spark	Heat/ spark and external fire	Heat/ spark and external fire	Battery heat, external heat/spark

Modes of fire spread	Heat	Fuel pool	Fuel pool	Short lived jet flames, flame length up to several metres	Jet flame, flame length up to several metres resulting to quick fire spread	Jet flame, extensive flame length up to several metres resulting to very quick fire spread	Short lived jet flames Scatter of hot objects, mainly for cylindrical cells
Main hazards - Worse case scenario	Fire Haz smoke/gases Exploding tyres, airbags, gas springs	Fuel pool Haz smoke/gases	Fuel pool Haz smoke/gases	Thermal runaway haz gas release, explosion/ignition risk. Unpredictable battery contribution 50% extra HF gas from fire compared to ICE	Gas boil off (for LNG only) Tank explosion Explosion/ BLEVE - only in case of pressure relief valve failure LNG: Cryogenic hazards	Extensive jet flame (7-9 metres directed downward and rearward) Tank explosion (TPRD failure) Gas release: In enclosed deck: gas pocketing from high explosive GH2 under ceiling	Thermal run-away gas release, explosion/ignition risk
Distance considerations	If risk of tyre explosion safety distance 20 m with ear protection			Jet flames max 7-10 m, duration 1-2 min. Do not approach directly from the rear or the front of the vehicle, as it might move due to short circuit	Jet flames from PRV or TPRV 7-10 m, fading rapidly. At risk of explosion safety distance 25 m with ear protection for personal car tank. For large tank (heavy vehicle), stay outside the space	10m jet flames during TPRV release. If risk of explosion 30 meters safety distance with ear protection	

Suppression/ manual fire fighting (first response only)	Water/Powder/ Foam Water on burning vehicle components cool tank	Water/Powder / Foam Water on burning vehicle components cool tank	Water/Foam Water on burning vehicle components cool tank	Water on burning vehicle components	Water on burning vehicle components Take into account the danger of BLEVE (in case of prolonged thermal radiation)	Water on tank Water on burning vehicle components	Water on battery Water on burning vehicle components
Containment	Drencher/ Hose	Drencher/Foam	Drencher/Foam	Drencher/extra water	Drencher	Drencher	Submerge battery in water/ Hose
Post fire	Cool until temp is low	Cool until temp is low	Cool until temp is low	Monitor, risk of spontaneous re-ignition. Cool with water	Cool until temp is low. Maintain safe distance to tank. Blow off by PRV's. Prevent freezing of the blow-off safety device (through contact with water). Control Ventilation / wind direction to prevent accumulation explosive gasses	Cool until temp is low	Ensure cooling Monitor