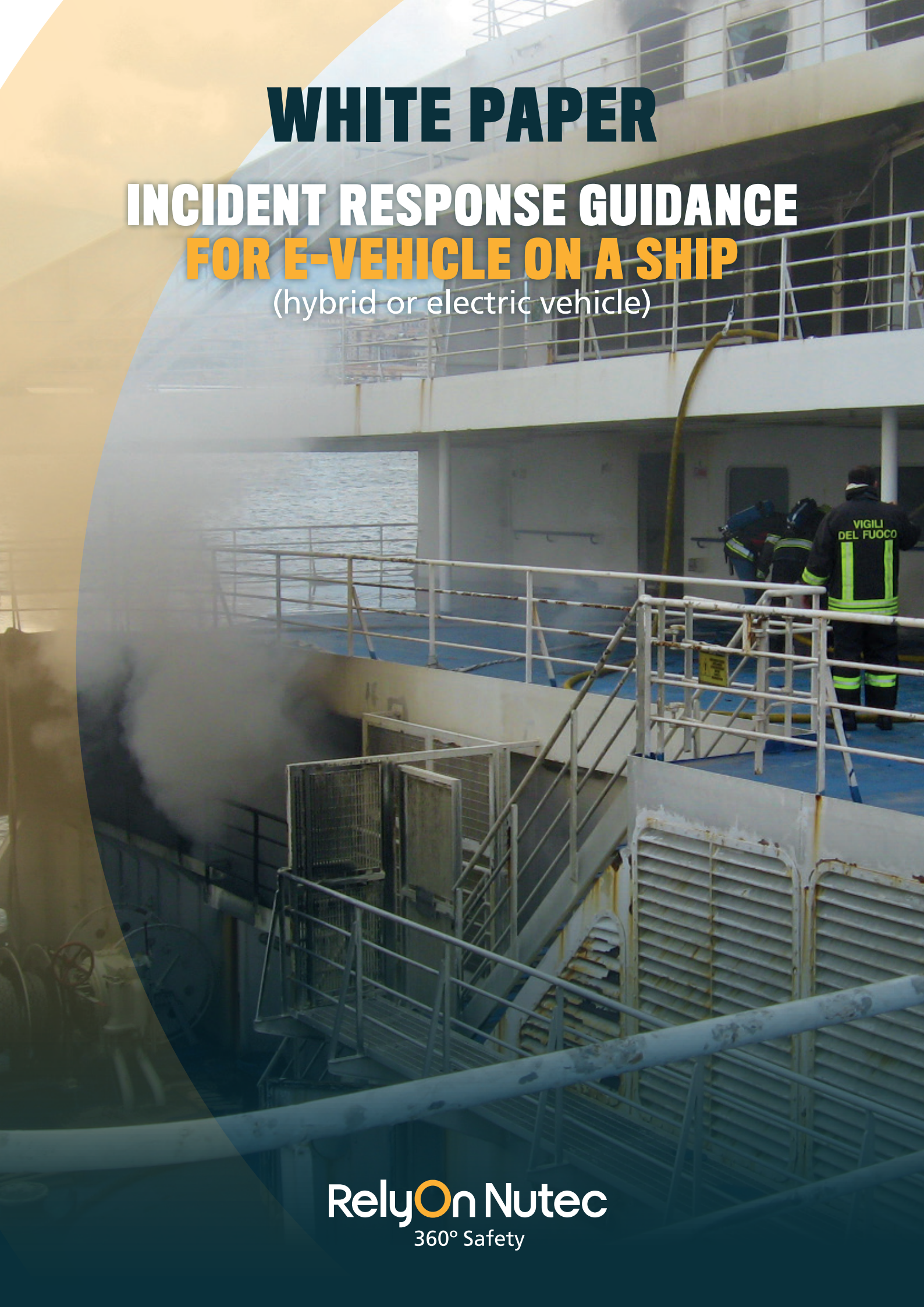
WHITE PAPER

INCIDENT RESPONSE GUIDANCE FOR E-VEHICLE ON A SHIP

(hybrid or electric vehicle)



RelyOn Nutec
360° Safety

INTRODUCTION

The FIRESAFE studies commissioned by EMSA have been the basis of the IMO work on reviewing and updating the fire safety standards of ro-ro passenger ships. A first result of this work has been adopted by the IMO for the Interim Guidelines (MSC.1/Circ.1615) related to this topic.
The IMO Maritime Safety Committee issued the interim guidelines for controlling fires in ro-ro spaces last year. It states that there should be:

> ***3.2.*** *Appropriate training and drills*
> ***3.2.1.*** *Relevant crew members should be trained on fire-fighting strategies and risks associated with alternatively powered vehicles such as battery or gas driven vehicles.*

RelyOn Nutec takes this seriously and has included the safe handling of incidents with alternative fuels in the course material for the Basic Training and Advanced Firefighting Training. As the refresher training has a 5 year interval, we deem this too long before you receive an update in this subject. Therefore we will provide you with this information guide about dealing with incidents with vehicles equipped with a high voltage Battery Power Pack. Especially the Li-ion batteries can be reactive if damaged.

Dangers of E-vehicles

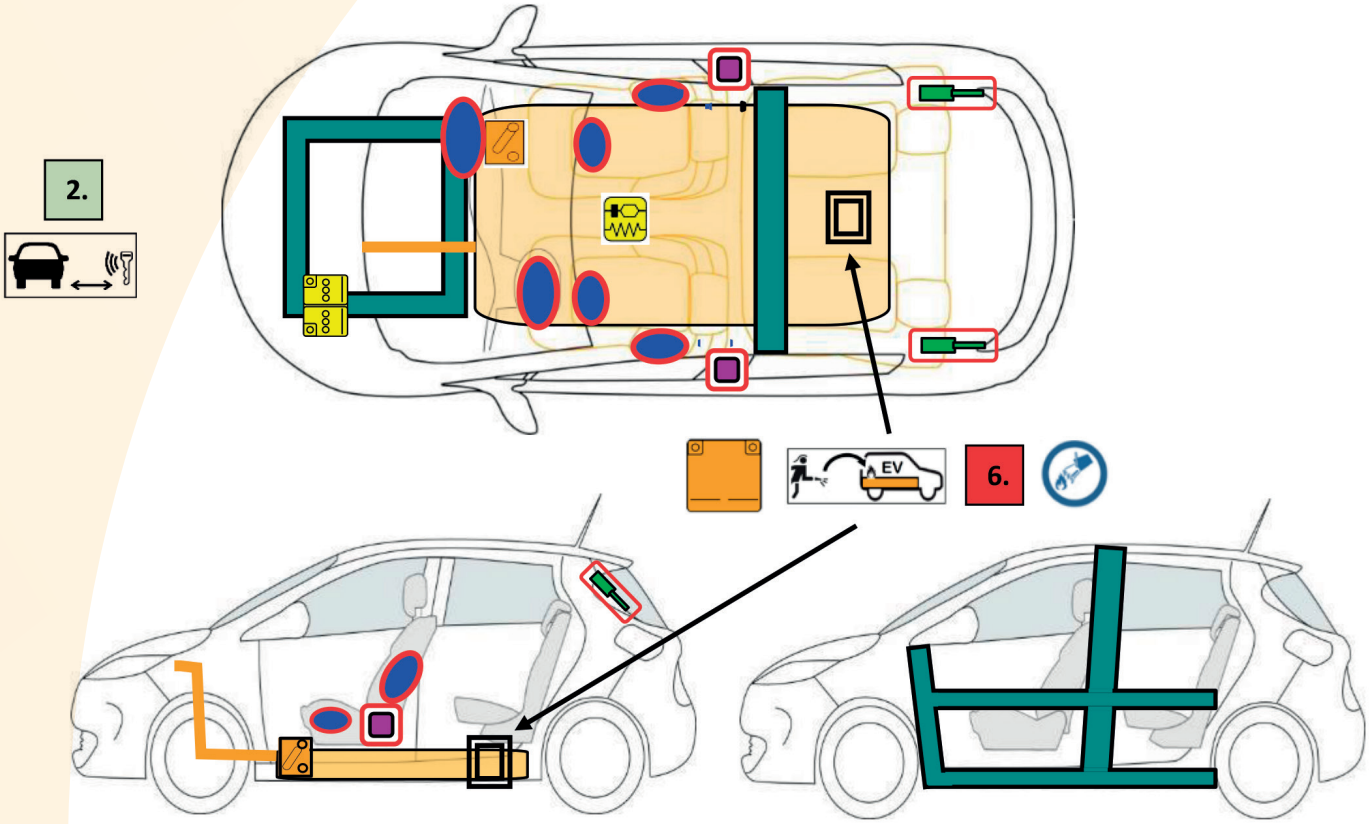
The presence of an high voltage (HV) battery pack in a vehicle generates additional hazards.

- The generation of fire, explosion and the release of toxic gases by a thermal runaway of a battery pack. A thermal runaway can start at 60°C and can continue for weeks.
- High Voltage (HV) from battery packs and cables. There may be voltage difference between the battery pack and the vehicle, which may cause arcing between the two.
- The presence of a continuous power supply when the vehicle is at a charging station.
- In a fire situation large quantities of highly toxic Hydrogen Fluoride (HF) may be released.
- Spontaneous rolling of the vehicle.
- Vehicles may also contain a fuel cell (hazard and mode of operation for Hydrogen (H2).

Characteristics of E-vehicles

- Hybrid passenger cars are often recognizable by the name 'Hybrid'.
- The name of electric vehicles regularly includes electrical references such as e-, E, PHEV, HEV, electric, Ampere, Volt, but there are also vehicles without these references such as Renault ZOE, Nissan LEAF, Tesla etc.
- An all-electric vehicle has no exhaust pipe. The charging plug can be located in various places around the vehicle.
- In a passenger vehicle the battery packs are usually located in the back and/or on the bottom plate. Some battery packs, especially those build into or under the vehicle compartment, are not easily accessible.

INCIDENT MANAGEMENT ON E-VEHICLES



PPE and tools:

- Correctly donned dry firefighter's clothing (MED/EN 469) and other PPE.
- Self-Contained Breathing Apparatus (SCBA).
- SCBA for support teams during degassing battery pack (if that's not possible; ventilate the space).
- 1000 V Electrical Safety Gloves with a cuff that extends over the sleeve of the firefighter jacket.
- Thermal Imaging Camera (TIC).
- 4-Cell Multi gas detector (H_2S, CO, O_2 and LEL).
- Dry electrical insulating tool.

Information about vehicle specifics

Find out from the vehicle type or characteristics (fuel fill points and charging connections etc), FIA data sheets (http://rescuesheet.info/index.html) or NFPA Electric Vehicle Field Guide, information on energy source/fuel, high voltage power cable routing, vehicle construction, safety devices and powertrain deactivation.

Note: Hydrogen Fluoride is a highly toxic substance and therefore regular firefighting bunker gear has very limited protection against full exposure.

STANDARD OPERATING PROCEDURES, EV FIRE

Thermal runaway of a Li-ion battery in a controlled environment

SOP Scenario; Fire

If there's a fire, it's relevant to know what's burning. If the Li-ion battery pack is involved in the fire, this means that it must be cooled with a lot of water for a long time. This could prove problematic to apply water to cool the battery packs due to their concealed location in the vehicle.

A NiMH battery pack in a Hybrid vehicle can be extinguished like a normal vehicle.

- If necessary, evacuate the entire car deck.
- Make sure that the vehicle cannot move/roll.
- Manned vehicle;
  - Evacuate occupants and park the vehicle and apply the parking brake.
  - Turn off the engine and keep the key at least 5 meter away.
  - Lock the wheels.
- Stay out of the (visible) toxic flue gases and vapours.
- Location open deck;
  - Approach the vehicle from the front at an angle of 45 degrees with 2 fire hose with low pressure nozzles from a distance. Although attacking from the front it's not always easy to identify the type of vehicle and fuel source, attacking from the rear of the vehicle may have additional hazards, such as fuel and gas strut explosions and vehicle parts are most likely to fly off from the force of the water jet. Use the angle to attack the fire in case the vehicle should roll forward or back.
- Location ro-ro or Parking deck:
  - Activate sprinkler/drenching system from section above the vehicle.
  - Activate exhaust ventilation
- Prevent spread of fire to other vehicles by cooling the adjacent vehicles until access to the vehicle has been established.
- Once accessed extinguish the burning Li-ion battery pack with 2 fire hose with low pressure jets (1 nozzle for battery pack and 1 nozzle for the vehicle).
- Continue to cool the Li-ion battery pack for a long time with a low pressure jet or water sprinkler or drenching system.
  - The cooling time depends on the temperature of the battery pack. A thermal runaway of a Li-ion battery pack is possible from approx. 60°C. This can last from days to weeks!
- If it is not clear what type of battery pack is involved, please follow the Li-ion battery procedure.
- If the Li-ion battery pack involved in the fire, fight the fire in the usual way.
- Keep monitoring the temperature of the battery pack with a Thermal Imaging Camera (TIC) to identify a possible thermal runaway.
- Keep in mind that during damping down after the fire that there may be a number electrical devices being carried in that vehicle containing Li-ion battery technology, which have potential to cause further harm.
- Notify port of arrival and hand over the vehicle to a specialised e-vehicle recovery company. After transfer, continuous temperature monitoring and, if necessary, cooling remains important.
- Arrange the disposal of any of the released electrolyte (toxic) and the cleaning of the deck.
- Pay attention to the pollution and discharge of the possibly contaminated fire extinguishing water in the sprinkler water storage or drain tanks.

STANDARD OPERATING PROCEDURE SCENARIO DAMAGED BATTERY PACK

SOP Scenario; Damaged battery pack
A damaged battery pack may still ignite. An indicator for this is the deformation of the vehicle. If the vehicle is heavily deformed, there is a good chance that the deformation will also affect the battery pack, which can Induce a thermal runaway in the case of a Li-ion battery pack.

- If necessary, clear the entire car deck.
- Make sure that the vehicle cannot move/roll.
- Manned vehicle;
  - Evacuate occupants and park the vehicle and apply the parking brake.
  - Turn off the engine and keep the key at least 5 meter away.
  - Lock the wheels.
- Observe for smoke and hissing noises indicating a thermal runaway (possible from approx. 60°C).
- Inspect with a Thermal Imaging Camera (TIC) the underside of the vehicle (where the battery packs may show thermal exposure) after damage has occurred and repeatedly at intervals looking for signs of thermal runaway.
- Use the 4-Cell Multi gas detector to measure flammable and toxic gases.
- Stay out of any (visible) gas clouds.
- Prepare a fire hose with low pressure nozzle
- If possible, approach the vehicle from the front at an angle of 45 degrees and have a fire hose ready.
- Immediately start cooling the battery pack with a fire hose from a throw distance to avoid a thermal runaway. This may be difficult to achieve without assessing the battery compartment. Monitor the temperature of the Li-ion battery pack with a TIC. In case of a thermal runaway, cool excessively with fire hose if you can reach it or activate drenching system. The cooling time depends on the temperature of the battery pack. A thermal runaway can last for weeks!
- In case of a smoking / hissing battery pack, everyone should be provided with Self-Contained Breathing Protection (SCBA) to avoid inhalation of Hydrogen Fluoride (HF). If this is not possible, provide fresh air in the vehicle and ventilate the area (100% ventilation).
- Low electrocution hazard. Wear dry, fully enclosed firefighter clothing and PPE, SCBA and 1000V gloves with the cuff over the sleeve of the firefighting gear, use dry insulating tools and maintain a distance equal to the throw length of the hose.
- Notify port of arrival and hand over the vehicle to a specialist e-vehicle recovery company. After transfer, continuous temperature monitoring and cooling if necessary remains important.
- Regulate the discharge of the released electrolyte (toxic) and the cleaning of the deck.
- Pay attention to the pollution and discharge of the possibly contaminated fire extinguishing water in the sprinkler water holding tanks.

SOP SUMMERY

INCIDENT E-VEHICLE						
1. Battery on Fire	yes			no		
2. Battery damaged	yes		no	yes		no
3. Persons involved	yes	no		yes	no	
Actions:	• Rescue. • Firefighting. • Prevent escalation. • Excessive cooling.	• Firefighting. • Prevent escalation. • Excessive cooling. • Battery monitoring continuously.	• Firefighting. • Battery check (regular)	• Rescue. • Battery monitoring continuously. • Cooling if temperature increases.	• Battery monitoring (continue). • Cooling if temperature increases.	
After care:	Handover E-vehicle to a shore based EV recovery company					

Are you prepared?

- Do you have the right PPE/devices for this new threat?
- Do you have the right procedures on board?
- Can you bring enough cooling power to every incident?
- Can you mitigate a controlled burn of vehicle/device?
- Are you sufficiently trained to recognize EV's and deal with the consequences an incident involving an EV?

EXPLANATION

E-vehicles

In the NEN 9140(NL) Working safely on e-vehicles, e-vehicles are defined as follows:
e-vehicles are vehicles or motor vehicles equipped with an electric traction system (NEN 9140). This includes vehicles with an all-electric or hybrid propulsion system: bicycles, mopeds (two-wheelers), vehicles for the disabled, motor vehicles, trams and cars.

NiMH and Li-ion battery packs

A hybrid vehicle uses two engines that together drive the vehicle: an internal combustion engine and an electric motor. Hybrid vehicles almost always have a nickel-metal hydride battery pack (NiMH). No thermal runaway occurs in these battery packs.

An electric vehicle (EV) is propelled by an electric motor, which uses electricity derived from, for example, chemical energy stored in lithium-ion (Li-ion) battery packs. The advantage of the - newer - Li-ion battery packs is that they have a higher energy density and a lower weight. Li-ion battery packs come in different types, e.g. LMO (Lithium Manganese Oxide; $LiMn_2O_4$) NCA (Lithium Nickel Cobalt Aluminium Oxide; $LiNiCoAlO_2$) and NCM (Lithium Nickel Manganese Cobalt Oxide; $LiNiMnCoO_2$). What they have in common is that they can become unstable during overcharging, deep discharging, high and low temperatures (-20 °C and > 60 °C) and the impact of a blow or crash. At worst, this can lead to short-circuiting, thermal runaway and fire, releasing highly toxic pyrolysis products.

Thermal runaway

A thermal runaway can be caused by:

- a mechanical damage/deformation
- an electrical fault (overcharging of the battery, over-discharge, short circuit, production faults)
- overheating (from 60 °C).

In a thermal runaway, the chemical reaction in the battery pack is 'runaway' and a lot of heat is produced within a short period of time. As a result, the battery pack fails, toxic substances are released and fire(-phenomena) and explosions of battery cells are possible.

Some tactics are prolonged cooling with excessive amounts of water (two to three times more than normal) or submerging the car (battery) in a water tank/container until no more gas bubbles are released. It is important to keep monitoring the temperature for a long time - several times - and to bring the vehicle (or have it brought) to a safe place, at least 15 meter away from other objects.

Toxic substances

In the event of a battery pack fire in a vehicle, Hydrogen Fluoride (HF), among other things, is released. The spray of the nozzle provides adequate protection against HF penetration. Therefore, approach the electric vehicle as a normal (dirty) interior fire and keep the exposure time as short as possible. Always wear firefighting clothing and independent respiratory protection.

Electrocution

The risk of exposure to electricity is extremely low because a battery pack is electrically disconnected from the vehicle body. The chance of a circuit running via earth is therefore negligible. The deformation of the battery pack in the event of a severe collision can lead to an electrical connection (direct current). In the literature it can be found that contact with a direct current of up to 120 volts will not have fatal consequences. During liberation actions, emergency services workers lean with body parts against the wreck; this cannot be prevented. Dry, completely closed firefighter clothing, the use of 1000V gloves and the rubber soles of the firefighter's boots provide a certain degree of protection. A scientific substantiation of the dangers of DC voltage and (sufficient) protection against this by the use of firefighter clothing and 1000V Electrical Safety Gloves is still necessary.

Transfer to EV recovery company

On shore there are salvage companies that can place an e-vehicle in a container with water in just a few hours to prevent the risk of re-ignition. This is not possible on a ship. So permanent monitoring must be organised for the first 24 hours and then periodic monitoring. Even after handover to a salvage or recovery company, the storage of the wreck is a point of attention in view of possible re-ignition and the environmental consequences.

Aftercare

The extinguishing clothing and personal protective equipment used are chemically contaminated after extinguishing and must be treated and cleaned as chemically contaminated clothing after use. The combustion residues and electrolyte of a battery pack is harmful to health and the environment and must be treated as chemical waste.

Environment

Ships with a ro-ro deck are equipped with drain, storage or holding tanks under the sea line to collect the extinguishing and drenching water. These can be heavily polluted by the extinguishing and drenching water.

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