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Fachbereich AKTUELL Subcommittee Fire and Emergency Services

Instructions for lithium-ion battery firefighting in vehicle fires

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The number of fire calls to traffic accidents or car fires involving hybrid and electric vehicles is currently on the rise. This also gives rise to questions about possible hazards and safe firefighting methods in vehicle fires where lithium-ion batteries[1] are also affected by the fire.

Fighting of car fires that involve lithium-ion batteries is generally not much different than fighting fires in conventionally powered vehicles (e. g. gasoline or diesel vehicles). The instructions listed below are meant to provide assistance.

This Fachbereich AKTUELL refers to series-production vehicles. However, it can be considered only a rough guideline when it comes to small series or individually retrofitted vehicles.

1 Characteristics of lithium-ion battery fires in electric vehicles

Lithium-ion batteries are used, in particular, as energy storage for the high-voltage system (high-voltage battery); sometimes they are also used for the 12 to 48 volt on-board power system. High-voltage batteries are normally installed in a stable, largely watertight box that is safely integrated in the vehicle structure (e.g. in the undercarriage). That is why the firefighting water cannot reach the fire source in the event of a fire inside a lithium-ion battery that is damaged only insignificantly. External cooling is hardly effective either because the cells are increasingly thermally insulated towards the outer shell. Tests and former operational experience has shown that this will prolong the firefighting operation and require larger amounts of firefighting water. Experience has also shown that a fire in a lithium-ion battery will be extinguished only once sufficient amounts of water can reach the inside of the lithium-ion battery. Tests have shown that water is both suitable and recommended as extinguishing agent. Extinguishing additives are not required. Not every (high-voltage) battery installed in a vehicle is a lithium-ion battery. Other technologies (e. g. nickel-metal hydride, NiMH) are installed for example in many hybrid vehicles. They are less reactive and also less dynamic in terms of their fire behavior. Burning lithium-ion batteries just like other fires release considerable amounts of respiratory toxins as well as harmful combustion products and residues.

2 How a lithium-ion battery burns

Lithium-ion battery fires can be caused, for example, by mechanical damage as well as by internal and external thermal events (e. g. flames or short circuits).

When burning, the fire can spread from cell to cell inside the battery. The smoke produced by a reacting lithium-ion battery appears mostly in form of a cloud of smoke the color of which alternates from light gray to deep black. Here, combustible electrolyte (usually white smoke) and graphite (usually gray smoke) is blown off.

Periodic explosive flames can form outside the battery as a result of the vaporizing, combustible electrolyte. Moreover, glowing metal parts and other burning parts of the battery may be eject-

1 Lithium-ion battery is used herein as a catchall term for a plurality of different battery types, including lithium-ions, lithium-polymer, lithium iron phosphate.

ed as a result of short circuits. Due to the high temperatures arising during a fire, one must expect holes to be burnt in the area of the battery box that is not readily accessible to the firefighters. Said holes and the present pressure-release openings allow for some of the extinguishing agents to enter the lithium-ion battery.

The spread of the fire depends, inter alia, on the design and arrangement inside the battery, on the cell chemistry and, in particular, on the battery's state of charge. Therefore it cannot be predicted with certainty.

3 Identification of hybrid and electric vehicles

Retrieving data from the competent rescue control center based on the vehicle registration number provides positive information on the type of drive technology used and allows for assigning the proper rescue data sheet. If possible, one should therefore ask for the vehicle registration number already during the emergency call. The person calling should also be asked whether it can provide further information on the vehicle type.

There are no standard exterior distinguishing vehicle features that would allow for identifying the type of drive technology. However, aside from questioning the driver there are also external indicators that can provide information as to the type of drive technology (EUTS Rules[2]). In case of hybrid and electric vehicles, this includes e.g. labels or imprints on the vehicle, orange cable connections, a READY display, charging connections or the absence of an exhaust system.

If the vehicle has an E label on the license plate, it is likely (due to the range requirements) to have a lithium-ion battery installed.

Please note: Vehicles lacking an E label may still include a hybrid or electric drive and be equipped with one or more high-voltage batteries.

2 **I**nspect **e**scaping operating fluids, **u**ndercarriage, engine compartment and trunk (orange cables, gas containers, tanks, high-voltage batteries), open **t**ank cap (extra charging connection), scan **s**urface (type identification, labels)

4 Fighting vehicle fires

When fighting car fires, firefighters are faced with potential risks regardless of the type of drive technology. Especially a fire inside a vehicle will result in total loss very soon, which is why low-risk firefighting tactics should be chosen whenever possible. Therefore, the following general tactical safety instructions apply:

- **Flames, heat and respiratory toxins released during a fire:**
  Wear full protective gear for indoor firefighting, incl. respiratory protective device (PPE (personal protective equipment) 12 pursuant to DGUV (German Social Accident Insurance) Information 205-014).
- **Rolling:**
  Burning vehicles may start moving independently, which is why they should be secured from rolling as soon as possible.
- **Heat radiation:**
  Start fighting the fire by using the throwing range of the firefighting nozzle solid jet and approach the vehicle diagonally from the corners only once the firefighting operation shows a first effect.
- **Flying debris:**
  The fire impact can result in flying debris (e.g. airbags, gas-filled shock absorbers, tires, burning light metals).

Approaching the vehicle diagonally from the corners ensures the greatest possible distance to the direct danger zone.

In case of a hybrid or electric vehicle, the following applies in addition (regardless of the high-voltage battery type):

Due to its design, it is unlikely that the high-voltage system of hybrid or electric vehicles will pose an electrical risk to firefighters. Nevertheless, the high-voltage system of said vehicles is still an electrical system in terms of DIN VDE 0132, which is why the safe distances specified therein should be observed when fighting a fire (low voltage: spray jet –1 m, solid water jet –5 m).

If and insofar as a burning hybrid or electric vehicle is still connected to the charging infrastructure via a charging cable, said connection should be disconnected or switched off in the course of the firefighting operation. Please note that the charg-

ing plug will be also mechanically locked if the vehicle is locked and that it may have to be removed by force.

5 Indicators that the lithium-ion battery is also on fire

A lithium-ion battery will not necessarily catch fire during a vehicle fire. Fire tests have shown that lithium-ion batteries must be heated from the outside over a longer period of time or must be heavily mechanically damaged before starting an internal reaction. The rescue data sheet provides information on the site of installation and (possibly) type of the battery/batteries. This allows for assessing whether the battery may be affected and also what type of battery one is dealing with. Indicators that the lithium-ion battery is also on fire may be, for example:

- Smoke coming from the battery
- Noise development (hissing, whistling, or rattling noise)
- Flying sparks and explosive flames coming from the battery
- Abnormal aromatic odor
- Increase in battery box temperature over a longer period of time, e.g. as observed with an infrared camera

6 Firefighting of lithium-ion batteries in vehicles

While a vehicle fire can be extinguished with conventional means, a lithium-ion battery may continue to burn for lack of accessibility. The following options are available to fight a lithium-ion battery fire, for example:

- Use large amounts of firefighting water. This will cool down the battery from the outside and water can enter the battery through openings (that have formed). A second line may be used to cool the lithium-ion battery. It may also be necessary to notify the sewage treatment plant and the competent environmental agencies.
- Another option is to let the lithium-ion battery burn under control in the vehicle that is no longer on fire. The risk of re-ignition will be reduced as soon as the battery cells have reacted to exhaustion or have burnt. Combinations of this and the above option are also conceivable.
- Firefighting water may be possibly introduced to the inside of the battery via an opening provided for by the vehicle manufacturer. Information regarding the location of such openings can be found in the rescue data sheet. It is recommended to start introducing water into the battery only once all vehicle occupants have been rescued.
- Submerse the affected vehicle in water (e.g. in a container) until the high-voltage battery is completely immersed under water. This will cool the battery from the outside. Moreover, water will be able to enter the battery through openings in the battery box, accelerate energy reduction and finally extinguish the fire. If the battery remains in the water quench for a sufficient period of time (several days), the individual battery cells will discharge which will reduce the risk of re-ignition. However, this requires great logistical effort. One should use only as much water as is necessary to completely submerse the high-voltage battery. The firefighting water needs to be professionally disposed of.

This method should be applied only in well-founded exceptional cases. It will not be generally necessary for the fire departments to hold available special containers.

! Attention!

There are hand-held fire extinguishers available in the market which penetrate the battery box to introduce firefighting water inside the battery. In this case, the operator is in the immediate vicinity of the battery. Since according to the state of the art this procedure does not comply with DGUV Regulation 49, Sec. 26 “Electrical hazards”, this method cannot be recommended at this point. This method is associated, inter alia, with the risk of partly considerable explosive flame formation; hazards to the firefighting team caused by electricity (e.g. electric arc, dangerous electric shock) cannot be excluded. In their operating instructions, vehicle manufacturers also prohibit to open or damage high-voltage batteries.

7 Measures following firefighting

Upon completion of the firefighting operation the vehicle should be deactivated as provided in the rescue data sheet, if possible. Lithium-ion batteries in a vehicle that have been damaged by mechanical or thermal action but do not show any indication of an ongoing fire (see under 5.) should be handed over to a towing service with the following safety instructions:

- The vehicle must be parked outside, separated from other vehicles. This will reduce the risk of a fire spread in case of re-ignition. If possible, the vehicle should be protected from climatic conditions (e.g. covered with a tarpaulin).
- The towing service must notify the vehicle manufacturer or one of its service partners so that the battery can be professionally removed, discharged and transported. Special provisions such as the ADR[3] apply to damaged lithium-ion batteries.

It is not recommended to submerse hybrid or electric vehicles in a water-filled container as a preventive measure.

To following applies regardless of the type of drive technology used in the motor vehicle on fire: please observe fire site hygiene rules! Protective gear and equipment contaminated by fire smoke and other combustion products or residues should be treated in accordance with DGUV Information 205-035 entitled “Hygiene and Contamination Prevention for Firefighters”.

Additional Information

Taskforce of the Heads of the Professional Fire Brigades/German Fire Brigade Association: Expert recommendation on the risk assessment of lithium-ion storage media, 2018

DGUV Rule 105-049 “Fire Brigades”, 2018

DGUV Information 205-022 “Rescue and firefighting operations involving passenger cars with alternative drive technology systems”, 2012

DGUV Information 205-035 “Hygiene and Contamination Prevention for Firefighters”, 2020

DGUV Information 205-014 “Selecting personal protective equipment for firefighting operations”, 2016

German Commission for Electrical, Electronic & Information Technologies of DIN and VDE (DKE): “Firefighting and technical assistance in or near electrical installations”, DIN VDE 0132:2018-07

German Fire Protection Association (vfdb): vfdb-Guideline 06-01, Medical Technical Rescue after Road Traffic Accidents, 2019

German Association of the Automotive Industry (VDA): Accident assistance and recovering vehicles with high-voltage systems. FAQ, 2017

3 European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)

The following organizations have contributed to this publication:

The Berlin Fire Brigade
DEKRA Automobil GmbH
DEKRA Qualification GmbH
DKE/K 213 Firefighting and technical assistance in or near electrical installations
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