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Sprinkler Protection of Lithium Batteries

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VdS Leaflet

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Contents

1 Introduction 4
2 Definition of terms 4
3 Basic classification 5
4 Extinguishing systems 6
4.1 Garages 6
4.2 Storage of lithium batteries 6
4.3 Production areas (assembly of devices, no battery production) 7
5 Recycling 8
6 Proof of effectiveness 8
7 References 8

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1 Introduction

Lithium batteries can be found in many areas of daily life. It is hard to imagine everyday life without rechargeable lithium ion batteries for mobile phones, notebooks, power tools and electric garden equipment, electric lawnmowers and bicycles, and they are also being used in the automotive sector in the onward march of electromobility.

The energy content is much greater in comparison with conventional battery technologies, meaning the energy released and the extent of damage in the event of fire can increase significantly.

Specific dangers in lithium battery technology are self-ignition and intense fire events connected with very fast fire spread. The associated risks represent particular challenges for fire prevention. Lithium batteries are always categorised as dangerous goods in regard to transport law and are subject to dangerous goods regulations during transport.

This Leaflet is primarily concerned with lithium ion batteries as these have been most frequently used in the familiar fire tests and are also currently the most widely used. It may be necessary to take other actions when applying it to other types (e.g. lithium-metal).

This Leaflet was developed by a VdS project group with representatives of the insurance trade, industry and experts.

2 Definition of terms

anode und cathode: In electro-chemistry, the electrode where oxidation takes place is called the anode, and that where reduction takes place the cathode. When charging a cell, the current direction and all processes in the cell are reversed. However, in batteries and accumulators, anode and cathode always correspond to the situation of discharge, regardless of the actual direction of current flow. The anode is thus the negative electrode, and the cathode the positive electrode.

BMS: battery management system

electrolyte: chemical compound which occurs as a solid or a liquid in batteries and contains free ions

power density: gives the electrical power (energy per given time) that can be drawn from a battery in relation to its mass. Power density is especially important in electromobility, as this requires light batteries that are able to deliver enough energy to accelerate the vehicle very quickly. Power density is given in W/kg.

lithium batteries: batteries with substances containing lithium. There is a basic distinction between lithium metal and lithium ion batteries. Lithium metal batteries contain pure lithium in small quantities. Lithium ion batteries usually contain lithium dissolved in other substances.

nominal energy: the energy that a fully-charged battery or accumulator can deliver under defined conditions (calculated as the product of the nominal capacity and the nominal voltage, e.g. 1 Ah x 3.6 V=3.6 Wh)

nominal capacity: the stored electrical charge of a fully charged cell or battery which can be drawn when discharging under defined conditions (example: a battery with a nominal capacity of 1000 mAh can be discharged for 1 hour at a current of 1 A)

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pouch cell: In contrast to the cylindrical or prismatic cell, the pouch cell has no solid housing but instead has a surrounding metal-plastic foil.

primary battery: non-rechargeable battery

prismatic cell: prismatic cells are often used in mobile phones, notebooks or cameras and are usually protected by a solid plastic casing.

secondary battery: rechargeable battery (accumulator)

SOC (State of Charge): charging status of the battery or accumulator in %

thermal runaway: burnout of a battery or accumulator, i.e. the electrical energy is released within a short time. Thermal runaway can be triggered by damage (e.g. fire or mechanical impact) or over- or under-discharge (deep discharge).

3 Basic classification

An essential finding from research reports and fire tests is that strong cooling of lithium batteries is essential for extinguishing fires. Water is favoured as the extinguishing agent for this cooling. Other extinguishing agents such as extinguishing gas or aerosols use the inerting effect. There is still insufficient evidence of whether this would be effective to protect stored batteries. However, research in this area is still continuing and so more findings are expected in the next few years.

A critical issue in relation to batteries containing lithium is thermal runaway. To prevent this, cooling of the batteries not involved in the fire is necessary. As this is difficult, if not impossible, in block storage, the risk of thermal runaway shall be minimised.

The charging process after a deep discharge represents a critical procedure. If batteries are to be charged, it should be ensured that these have not previously been deeply discharged (e.g., limit the storage time before charging to 6 months).

In order to make the results of fire tests and existing concepts more transferable, batteries can be classified as in VdS 3103. The weight of the batteries can vary greatly due to the different housings (e.g. pouch cells). Therefore, classification by energy content per storage unit (e.g. pallet) is more useful here. Classification into the following categories is a suitable option:

Hazard level (HL)	Risk	Energy content (kWh) / Storage unit
I	Low	< 1
II	Medium	1.0-50
III	High	> 50

Table 1: Classification of lithium batteries

Batteries are usually classified according to their power (Ah). As the voltages can also vary greatly, the power has been converted to kWh.

An incoming goods inspection shall ensure that only undamaged cells and batteries are stored, for which UN 38.3 is available as evidence of checking. Special consideration is necessary for prototypes, defective batteries or returns.

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4 Extinguishing systems

There is currently insufficient evidence about the protection of lithium batteries by water extinguishing systems. Tests carried out by FM Global[1] and GDV[2] in collaboration with VdS show that water is fundamentally suitable as the extinguishing agent. However, the results of the fire tests are not sufficient to recommend general design parameters for all types of batteries. If a facility in which large quantities of lithium batteries are stored or processed is to be protected, a facility-specific concept shall always be created. Insurers, developers of fire protection concepts and extinguishing system experts and, if necessary, the building authorities and fire protection offices shall be involved at an early stage.

Despite great care being taken, it cannot be ruled out that the recommendations for the design of extinguishing systems given in this Leaflet are shown to be insufficient in future – also due to the technical further development of batteries and extinguishing techniques – and that retrofitting will therefore be required.

4.1 Garages

According to official statistics, there were around 83,200 electric cars in Germany on 01.01.2019. Added to this are the batteries for hybrid cars and conventional vehicle batteries for the onboard electronics now based on lithium technology. It can thus be assumed that vehicles containing lithium batteries can be encountered in garages. Furthermore there are also charging stations which are being installed in more and more garages.

According to VdS CEA 4001, garages are classified as fire risk category OH2. Fire tests have shown that a burning vehicle cannot be extinguished as, for example, the car interior and the engine compartment cannot be completely covered with water. Neighbouring vehicles were, however, reliably prevented from catching fire. This protection aim can probably also be achieved for vehicles with lithium batteries. However, no appropriate fire tests have been carried out so far.

Fire occurrences have shown that drive batteries burn for a long time and can also reignite after a significant period of time. Therefore, the following is recommended for garage sprinkler systems:

– design according to VdS CEA 4001; Class 1; Fire Hazard Category OH 2
– operation time at least 60 minutes
– fire department supply connection

Further organisational measures are required where charging stations are present. An appropriate concept for this shall be set up. Instructions can be taken from the GDV publications VdS 2259 – Battery Chargers for Electric Vehicles and VdS 3103 – Lithium Batteries.

4.2 Storage of lithium batteries

4.2.1 Devices with lithium batteries

The following applies to devices with built-in lithium batteries – either fixed, or exchangeable (e.g. electric tools, robotic lawn mowers). These devices often consist to a large extent of plastic and/or are packed in plastic products (e.g. plastic box for a cordless screwdriver).

[1] RESEARCH TECHNICAL REPORT Development of Protection Recommendations for Li-ion Battery Bulk Storage: Sprinklered Fire Test; October 2016
[2] Research report on the investigation of sprinkler concepts to protect storage situations with lithium-ion batteries, 25.11.2015

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A possible protection concept is as follows:

- all devices are in drenchable packaging
- drive batteries for cars are not permitted[3]
- the stored energy per storage unit (e.g., pallet) shall not exceed 50 kWh (max. HL II according to Table 1)
- rack storage: design according to VdS CEA 4001, K.7.1 (Table K.7-1, category IV)
- sprinkler protection provided on every rack level
- block storage: design according to VdS CEA 4001, HHS4 + K.7

Mixed storage (e.g. goods distribution centres of warehouse chains) shall be protected as described above.

4.2.2 Battery storage

A possible protection concept for the concentrated storage of lithium batteries is as follows:

- all batteries are in drenchable packaging
- drive batteries for cars are not permitted
- the stored energy per storage unit (e.g. pallet) shall not exceed 50 kWh (max. HL II according to Table 1)
- these requirements are independent of the state of charge (SOC)
- rack storage:
  - design according to VdS CEA 4001, 11.5 + K.7 (cat. IV)
  - sprinkler protection provided on every shelf level
  - horizontal sheet metal barriers above each sprinkler level according to VdS CEA 4001, 11.6.2.5.2
  - face sprinklers shall be installed in each transverse flue in addition to the sprinklers in the central flue
- block storage:
  - maximum 20 m² blocks
  - 2.4 m aisles between the blocks
  - max. 1.5 m storage height
  - design density 17.5 mm/min
  - fast responding K160 sprinkler
  - maximum ceiling height: 12 m

4.3 Production areas (assembly of devices, no battery production)

Here a case-by-case analysis is always necessary. In production areas there are often large quantities of plastics which demand higher requirements. In general, regulations based on VdS CEA 4001, K.7.4 can be made for individual pallets with batteries in production areas.

[3] Tests indicate that the storage of one drive battery per storage unit in racks can be protected according to this concept. The tests were, however, carried out without the involvement of VdS and the results have not been published. Therefore, no recommendations can be given here.

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5 Recycling

Special consideration is required for the collection of used batteries and for recycling. The regulations in this Leaflet cannot simply be transferred.

6 Proof of effectiveness

As previously stated, fire tests are urgently needed for further findings. There are also no fire tests to confirm the recommendations given above. It could also be expedient to carry out object-specific fire tests for individual projects.

7 References

VdS 3103 Lithium Batteries

VdS 2259 Battery Chargers for Electric Vehicles

VdS CEA 4001 Guidelines for Sprinkler Systems – Planning and Installation

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