

VDMA 24994



ICS 55.220; 29.220.20; 13.220.40

Test requirements for fire-protection storage cabinets for lithium-ion batteries in the case of thermal runaway

Prüfanforderungen für feuerwiderstandsfähige Lagerschränke für Lithium-Ionen-Batterien im Falle eines Thermal Runaway

Document comprises 20 pages

VDMA

Contents

	Page
Foreword.....	4
1 Scope	4
2 Normative references	4
3 Terms and definitions	4
4 Classification and requirements	5
4.1 Classification.....	5
4.2 General Requirements	6
4.2.1 Technical design range (<i>TDR</i>)	6
4.2.2 Fire Protection.....	6
4.2.3 Door.....	6
4.2.4 Shelves	6
4.2.5 Cable Entry	7
4.2.6 Anchoring holes.....	7
4.2.7 Extract Air System	7
4.2.8 Ventilation Openings	7
4.2.9 Further Openings.....	7
4.2.10 Extinguishing system.....	7
4.2.11 Detection of critical events	7
4.2.12 Charging devices	8
4.2.13 Alert system	8
4.3 Minimum Requirements	8
5 Test specimen, technical documentation and correlation	8
5.1 Test specimen	8
5.2 Technical documentation	9
5.2.1 Construction details	9
5.2.2 User instructions	9
5.3 Correlation of test specimens and technical documentation	10
6 Test methods (Thermal Runaway from inside).....	10
6.1 General requirement.....	10
6.2 Test equipment	10
6.2.1 Test environment/test room	10
6.2.2 Thermocouples	10
6.2.3 Pressure sensor.....	10
6.2.4 Initiating the thermal runaway.....	11
6.2.5 Timing device	11
6.2.6 Equipment for weighing test specimens.....	11

6.3	Preparation of the batteries.....	11
6.4	Preparation of the test	12
6.4.1	General	12
6.4.2	Battery boxes	13
6.4.2.1	Standard test.....	13
6.4.2.2	Test without propagation blocking.....	13
6.4.3	Sensors	13
6.5	Test (Thermal Runaway).....	15
7	Test methods (fire from outside)	16
7.1	General requirement	16
7.2	Test equipment	16
7.2.1	Test environment/test room	16
7.2.2	Pressure and heating conditions.....	16
7.2.3	Thermocouples for the furnace temperature	16
7.2.4	Thermocouples inside the test specimen.....	17
7.2.5	Timing device.....	17
7.2.6	Equipment for weighing test specimens.	17
7.2.7	Preparation of the test	17
7.2.8	Test	19
8	Test report.....	19
9	Marking.....	20

Foreword

This VDMA Specification has been developed by the Ad Hoc Group “Testing and Certification of Storage Cabinets for Lithium-Ion-Batteries” together with experts of other organisations.

1 Scope

This document specifies test requirements for fire-protection storage cabinets for lithium-ion batteries. It tests the fire resistance of the cabinets in which a thermal runaway of batteries occurs and tests that the temperature outside of the cabinet does not rise above a certain level and that no projectiles or fragments go out of the cabinet during a thermal runaway. Classes I/O30, I/O60 and I/O90 additionally test the fire resistance of the cabinet from outside fires. The risks of toxic gases produced by the batteries are not tested by this document. To reduce the risk of toxic and flammable gases in case of thermal runaway an additional extract air system should be installed on site.

This document is applicable to detachable / portable lithium-ion batteries with a weight equal to or less than 25 kg. Active charging of the lithium-ion batteries may be possible inside the cabinet.

In order to take the worst case into account, the maximum possible energy of batteries on one shelf shall be tested. In order to ensure reproducibility of the test, this guideline assumes, that the thermal runaway occurs in a single battery box with the maximum possible energy per shelf.

This document is not applicable to not permanently installed storage devices, does not verify battery characteristics, and does not test active security/safety measures inside of the cabinet such as fire detection systems and fire extinguishing systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies

EN 54, *Fire detection and fire alarm systems (including all the parts)*

EN 1363-1:2020, *Fire resistance tests – Part 1: General requirements*

EN 13246, *Packaging – Specification for tensional steel strapping*

EN 15659:2019, *Secure storage units – Classification and methods of test for resistance to fire – Light fire storage units*

EN 60584-1:2014, *Thermocouples – Part 1: EMF specifications and tolerances (IEC 60584-1:2013)*

EN ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs (ISO 7010)*

ISO 17546, *Space systems – Lithium ion battery for space vehicles – Design and verification requirements*

VDA Recommendation 4500, *Small Load Carrier (KLT) System*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
Lithium-Ion battery
Rechargeable electrochemical cell or battery in which the positive and negative electrodes are both intercalation compounds (intercalated lithium exists in an ionic or quasi-atomic form with the lattice of the electrode material) constructed with no metallic lithium in either electrode (see ISO 17546).

3.2
Detachable Lithium-Ion battery
A detachable Lithium-Ion battery is a portable battery with a weight of ≤ 25 kg which can be removed from the entire system e.g. e-bike, battery drilling machine etc.

3.3

State of Charge (SoC):

The level of charge of an electric battery relative to its capacity, the units of SoC are percentage points (0% = empty; 100% = full).

3.4

Charge

Active charging of the battery by supplying electrical energy.

3.5

Storage

Storage of batteries without the supply of electrical energy.

3.6

Lithium-ion battery storage cabinet

Storage unit which protects the personnel/operator as well as the environment in the case of spontaneous ignition of lithium-ion batteries against fire from the inside of the cabinet and when closed has at least one internal side ≤ 1 m length and a maximum internal volume of 3000 l.

3.7

Thermal runaway

Uncontrollable condition whereby a cell or battery overheats and reaches very high temperatures through internal heat generation caused by an internal short or by a faulty condition.

3.8

Ventilation opening

Opening used for supply and extract air.

3.9

Shelf

Part of the cabinet used for storing batteries, either across the whole surface or divided into compartments.

3.10

Cable entry

Required opening for cables to the external power supply.

3.11

Anchoring hole

A hole in the cabinet by which the cabinet can be anchored to the floor or the wall.

3.12

Extinguishing system

Equipment used for the extinguishing of battery fires.

3.13

Smoke/gas detector

Devices that can trigger an alarm in the event of a fire due to smoke/gas development.

3.14

Critical event

event where the temperature is above 60°C and/or due to smoke a smoke detector is triggered.

4 Classification and requirements

4.1 Classification

The combination of classes ("I" for a cabinet tested against Thermal Runaway from the inside and "O" for a cabinet tested against fire from the outside) and times (only when tested from the outside) shall be deduced from test results.

NOTE Based on the test results changes that do not affect the resistance can be assessed, for instance by using clause 4.2.1.

Only those combinations of classes and times as defined in the following clauses of this VDMA Specification shall be used for the relevant elements. The classification(s) shall be awarded after verification that specific additional general requirements of 4.2 are satisfied.

The classification shall be presented according to the following template:

Tested against Thermal Runaway from the inside		Tested against fire from the outside	Period (30 min, 60 min or 90 min) during which all criteria against a fire from the outside is met.
I	/	O	t

Examples: The class "I" refers to a cabinet that resists against a battery Thermal Runaway inside the cabinet. The class I/O60 refers to a cabinet that resists against a battery Thermal Runaway from the inside as well as a fire from the outside for 60 min according to this VDMA Specification.

The resistance against a Thermal Runaway from the inside is either pass or fail according to the test criteria, no resistance time is given.

4.2 General Requirements

4.2.1 Technical design range (TDR)

Based on the technical documentation (5.2) the testing laboratory shall check if all applied models of the manufacturer are part of one single technical design range (TDR).

If models are not part of a technical design range, these models shall be seen as an additional technical design range. Models that cannot be assigned to the TDR shall be subjected to a separate type test.

Models are part of a technical design range if all the following points are fulfilled:

- a) Same product type (all having one door or two doors)
- b) Common construction features (type, specification and thickness of construction and materials, rabbet geometry, seals etc.)
- c) internal width and internal depth according to EN 15659:2019 Clause 5.2.

The models with the smallest and largest internal height of a technical design range (see Clause 5.2, EN 15659:2019) shall be tested (see also Annex A, EN 15659:2019).

4.2.2 Fire Protection

The cabinet shall be designed and constructed to ensure that, in the event of thermal runaway, its contents will not create risks from the spread of fire, projectiles and fragments, see 4.3.

4.2.3 Door

The door shall be lockable with a multi-point lock or a lock connected to a boltwork mechanism.

The door shall have a device that ensures that the cabinet door is not opened for more than 1 min, (for instance a self-closing system with self-locking, alarm system etc.).

If the closing of the doors is actuated or triggered by an external power source, the mechanism shall continue to work even if the external power source fails.

If a hold-open feature is included, the access opening shall be closed fully if the maximum opening time (1 min) is reached.

Moving components of the closing mechanism shall not reach into the usable space of the cabinet.

There shall be a notice on the door that the door shall always be closed.

It shall be possible to operate the door by hand.

4.2.4 Shelves

The shelves shall not interfere with the closing of the doors. This shall be checked before the test. Pull-out storage levels shall not cause the cabinet to topple, not even when it is fully loaded.

The shelves and the mounting methods shall be clearly specified in the technical documentation.

4.2.5 Cable Entry

There is no limitation on the number and the size of the cable holes.

The position, diameter as well the sealing of the opening(s) shall be specified in the technical documentation (5.2).

The minimum requirements according to 4.3 shall be met.

4.2.6 Anchoring holes

There is no limitation on the number and the size of the anchoring holes.

The anchoring holes shall be specified in the technical documentation (5.2).

The minimum requirements according to 4.3 shall be met.

A cabinet without any anchoring holes is permitted. For instance, the design of the cabinet may enable its evacuation in case of an internal fire, where the connections of the cabinet (e. g. power supply) can be quickly disconnected.

4.2.7 Extract Air System

Lithium-ion battery storage cabinets shall be equipped with openings enabling the connection of the cabinet to an extract air system.

NOTE If an extract air system is connected to the cabinet, then it should be constructed that at least a flow rate of 30 m³ per hour is possible.

The relevant details shall be specified in the technical documentation (5.2).

4.2.8 Ventilation Openings

Lithium-ion battery storage cabinets can optionally be equipped with ventilation opening(s).

The minimum requirements according to 4.3 shall be met.

If ventilation opening(s) will be used, the relevant details shall be specified in the technical documentation (5.2).

4.2.9 Further Openings

Lithium-ion battery storage cabinets can optionally be provided with further openings.

The minimum requirements according to 4.3 shall be met.

Openings for a short-term pressure relief (structural elements like flaps or doors, ventilation openings etc.) are also permitted. However, the pressure relief shall be designed in such a way that no additional risks arise for the spread of fire, smoke, projectiles and fragments.

If further opening(s) are used, the relevant details shall be specified in the technical documentation (5.2).

4.2.10 Extinguishing system

Lithium-ion battery storage cabinets can optionally be equipped with an extinguishing system.

If an extinguishing system is used, it shall be a part of the construction and it shall be a part of the cabinet test specimen. The extinguishing system itself shall be deactivated during the test.

If an extinguishing system is used, an appropriate detection system shall be installed in the cabinet, for instance, smoke/gas detector. If a detection occurs, at least an optical or audible alarm shall be triggered.

If an extinguishing system is used, the relevant details shall be shown in the technical documentation (5.2).

4.2.11 Detection of critical events

To detect critical events a temperature sensor that activates if the temperature inside the cabinet is above 60°C and a smoke detector according to EN 54 shall be positioned inside the cabinet.

NOTE To be able to notice hazardous gases or gases that may lead to an explosion, additional gas detection can be beneficial.

4.2.12 Charging devices

If devices are used to charge the stored batteries, there shall be an automatic emergency shutdown in case of the possibility that a thermal runaway occurs.

The device shall be activated according to the requirements set out 4.2.11.

4.2.13 Alert system

In case of a critical event (see requirements set out under 4.2.11) an optical and acoustic signal shall be provided on the outside of the cabinet at a highly perceptible position. In addition, there shall be a possibility to forward the alert-signal to an external control centre.

4.3 Minimum Requirements

Table 1 – Minimum requirements to pass the internal fire test

	Requirements for classes I, I/O30, I/O60 and I/O90
1	No visible flames shall come out from the cabinet during and after the thermal runaway.
2	The temperature of the escaping smoke and gases shall not exceed: <ul style="list-style-type: none"> – Temperature increase of 150 K (starting temperature outside of the cabinet of $(20 \pm 10)^{\circ}\text{C}$). – Measured in a distance of 26,5 ($\pm 1,5$) mm from the door gaps as well as any available openings.
3	The cabinet door shall not open or deform in such a way that the requirements of this Table are not fulfilled, due to the resulting pressure. Additionally, no projectiles and fragments shall come out of the cabinet.
4	The external surface temperature of the tested cabinet shall not exceed: <ul style="list-style-type: none"> – Temperature increase of 150 K (starting temperature outside of the cabinet of $(20 \pm 10)^{\circ}\text{C}$).
5	If more than one storage level is available, the propagation on the batteries/cells on a storage level above and/or under the tested batteries/cells shall be prevented. Alternatively, a test with batteries on all levels with maximum permitted energy shall be performed.

Table 2 – Minimum requirements to pass the external fire test

	Requirement for classes I/O30, I/O60 and I/O90
1	The requirements of this Table shall be met for 30 min for I/O30, for 60 min for I/O60 and for 90 min for I/O90. Cabinets of the class "I" are not tested against a fire from the outside.
2	One single thermocouple inside of the cabinet according to 7.2.7 a) to e) shall not exceed a: <ul style="list-style-type: none"> – temperature increase of 120 K (starting temperature inside of the cabinet of $(20 \pm 10)^{\circ}\text{C}$).
3	All other thermocouples inside of the cabinet according to 7.2.7 a) to e) shall not exceed a: <ul style="list-style-type: none"> – temperature increase of 100 K (starting temperature inside of the cabinet of $(20 \pm 10)^{\circ}\text{C}$).

5 Test specimen, technical documentation and correlation

5.1 Test specimen

The test specimen shall be tested as a free standing cabinet. The distance from the surrounding walls of the room shall be at least 750 mm. The distance to the back wall shall be (100 ± 5) mm

The models with the smallest and largest internal height of a technical design range (see Clause 5.2, EN 15659:2019) shall be tested (see also Annex A, EN 15659:2019) for the internal and external fire test.

The specimens shall be equipped with all intended options/variants.

Based on the technical documentation (see 5.2), the test laboratory determines the required cabinet test specimens.

In the case that the construction is equipped with special filling material (for instance insulation materials), then two (class I) or three (class I/O30, I/O60, I/O90) identical lithium-ion battery storage units shall be available for each size: Smallest and largest internal height of a technical design for the TR fire test (fire load from inside), smallest and largest internal height of a technical design for the external fire test (fire load from outside), one more for verifying correlation of the filling material with the technical documentation and to perform the weight changing test of 5.3. The testing laboratory shall decide which cabinet test specimen will be used for the type test.

5.2 Technical documentation

5.2.1 Construction details

Detailed technical documentation of the technical design range and cabinet test specimen (drawings, specifications of materials, installation- and processing advice) shall be submitted to the testing laboratory before the type test.

The documentation shall contain the following information:

- Table of sizes: Height, width, and depth of the models that should be part of the technical design range (inside and outside dimensions as well as weights)
- Weight of the cabinet test specimen
- Materials and their thicknesses
- Dimensions of rabbet edges
- Dimensions of the gaps around the doors and between them
- Welds including the method of their execution
- Seal arrangement and specification
- Door locking devices (for instance multi-point lock)
- Door self-closing system (if applicable)
- Specification, arrangement and mounting methods of shelves
- Specification of the cable entries
- Specification of the anchoring holes (if applicable)
- Specification of the extract system opening
- Specification of the ventilation openings (if applicable)
- Specification of further openings (if applicable)
- Specification of the extinguishing system (if applicable)

Samples and detailed specifications of all the heat protection materials and seals used in the cabinet test specimens shall accompany the cabinet test specimens.

5.2.2 User instructions

The series product shall be supplied with a user manual/operating instruction for the cabinet, which include at least the following:

- Instructions for the correct installation of the cabinet
- The maximum load energy (Wh), of each shelf and of the entire cabinet
- The types of batteries that are permitted to be used and/or shall not be used in the cabinet.
- Note: Any included charging devices will shutdown in the event of fire or overheating

- Warning that in the event of a fire and/or if an alarm notice from the cabinet is triggered, unlocking should only be performed by an authorized professional with appropriate personal protective equipment. Unlocking after the fire should be done in a secure area if possible.
- Instructions for closing and sealing cable openings that are no longer used.
- Maintenance instructions (a list of parts that need to be routinely inspected and/or replaced e.g., extinguishing system, ventilation system)
- There shall be a notice that the cabinet shall not be placed near fire loads.
- Note that the instructions of the battery manufacturer shall be followed.
- It is recommended to perform a risk assessment regarding whether additional safety measures are required to further minimize the risk of hazardous gases or explosion.
- Warning that batteries have a risk of producing toxic gases. It is therefore highly recommended to connect the cabinet to an extract air system. The extract air system should be constructed so that a minimum flow rate of 30 m³ per hour is possible. The extract air system shall not lead the gases into working areas. If the user does not connect the product to an extract air system the user should perform a risk assessment that no gases lead into active work areas, e. g. for instance to test the air tightness.

5.3 Correlation of test specimens and technical documentation

The cabinet test specimens and the supplied technical documentation shall correlate.

The weight of the specimen(s) shall be measured.

The wall and door thicknesses of the cabinet test specimen shall not exceed more than 3 % of the nominal dimensions in the technical documentation.

Photo documentation shall be made both before and after the test, with pictures of the open and the closed cabinet, detailed views of the doors, condition of the seals, etc.

All features (see 4.2 general requirements) shall be installed according to the technical documentation.

In the case that the construction is equipped with special filling material, then before the fire test begins, 250 g of insulating material, shall be taken from three different surfaces (e.g., door and wall) of one of the cabinets. The three samples shall be weighed and then dried for 24 h at $(40 \pm 1) ^\circ\text{C}$ and a relative humidity of 50 %. None of the three samples may weigh less than 95 % of the original weight.

6 Test methods (Thermal Runaway from inside)

6.1 General requirement

The test shall be performed by a testing laboratory, which is experienced in the area of testing batteries.

The fire endurance of the test specimen is assessed by triggering a thermal runaway in the test specimen.

6.2 Test equipment

6.2.1 Test environment/test room

The laboratory determines the test environment considering the risk. The laboratory is also responsible for the necessary safety measures regarding firefighting.

6.2.2 Thermocouples

Thermocouples of type K (NiCr-Ni) or type J (Fe-CuNi) with a measurement uncertainty according to EN 60584-1 for measuring the surface temperature on the cabinet test specimen shall be used.

Thermocouples of type K (NiCr-Ni) with a measurement uncertainty according to EN 60584-1 for measuring the escaping smoke/gas temperature shall be used.

6.2.3 Pressure sensor

The pressure sensor used shall meet the following requirements:

- pressure ranges from 0 bar to minimum 10 bar,
- scaling 1/1000 bar

6.2.4 Initiating the thermal runaway

The Thermal Runaway shall be initiated by a minimum of two cartridge heaters, Type HHP Ø 12,5 mm, 400 W / 230 V placed in the plastic box. The cartridge heaters shall be installed in a round copper rod with the same inside diameter as the heater and same outside diameter as the cells used. The copper rod shall allow a contact to all the neighbour cells. The temperature increase of the cartridge heaters shall be 15 K/min.

6.2.5 Timing device

A timing device, capable of running continuously throughout the test period shall be used.

6.2.6 Equipment for weighing test specimens.

Equipment for weighing test specimens, with an uncertainty of measurement of $\pm 3 \%$ shall be used.

6.3 Preparation of the batteries

In order to take the worst case into account, the maximum possible battery energy that is permitted on one shelf (according to the applicant) shall be tested. Therefore, the maximum energy (Wh), according to the applicant's specifications, will be achieved by placing individual cells standing upright in one level in one standardized plastic EUROBOX (see Figure 1 and VDA recommendation 4500). Only if it is not possible, to position the maximum energy on one shelf, it is permitted to position more than one level of cells on top of another inside of the battery box. To prevent the cells from flying off in an uncontrolled manner the box shall be tightly closed (for instance with tension straps, screws etc).

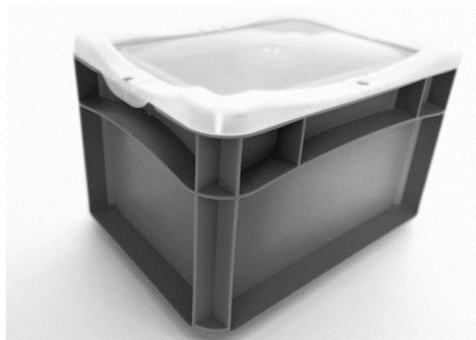
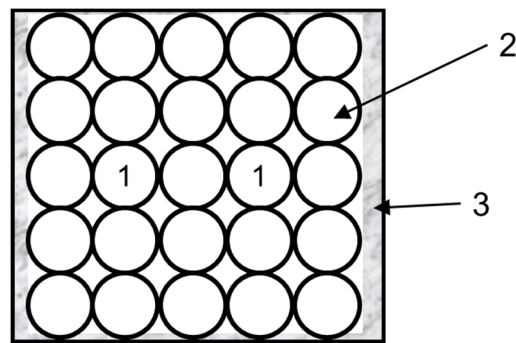


Figure 1 – Example of a battery box

The plastic box shall be prepared as follows (see Figure 2):

- Cells with Nickel-Manganese-Cobalt (NMC 8-1-1 or NMC 9-0,5-0,5) technology shall be used. The cells shall be tied together with a tensional steel strapping ((0,5 mm ($\pm 0,05$ mm)) x (13 mm ($\pm 0,5$ mm))) according to EN 13246, so that the spaces between the cells are as small as possible.
- The free space shall be as small as possible.
- The individual new unused cylindrical cells shall be fully charged (SoC > 98 %).
- Two cartridge heaters shall be placed in the centre of the battery box to trigger the thermal runaway. The connection cables shall be led out of the of the plastic EUROBOX cover.



Key

- 1 cartridge heater
- 2 fully charged battery cells
- 3 Free space (as small as possible)

Figure 2 – Preparation of the battery box

6.4 Preparation of the test

6.4.1 General

Cabinets shall be tested as a free-standing individual unit.

The test shall be performed in a controlled climate area ($(20 \pm 10)^\circ\text{C}$).

The cabinet test specimens and the lithium-ion batteries shall be stored in a controlled climate temperature of $(20 \pm 10)^\circ\text{C}$ for a minimum of 24 h prior to the beginning of the type test.

All openings shall be prepared and tested as stated in the technical documentation by the manufacturer:

- If cable entries are available, then the opening(s) shall be included in the cabinet test specimen and the cable routing shall be sealed (if provided) according to the manufacturer's specifications.
- If anchoring holes are available, then the holes shall be included in the cabinet test specimen.
If a closure of the opening is provided, then the holes shall be closed according to the manufacturer's specifications.
- The connection part to the extract air system shall be included in the cabinet test specimen. Only for the inside test:

At the start of the test the openings for the extract air system shall be tested as stated in the technical documentation, but without a connection to an **active** extract air system.

To generate a (low) counter pressure a flange (at least DN100) shall be connected to the cabinet on which a pipe (at least DN100) is connected including at least one 90° angle and a total system length of at least 3 m.

- Ventilation opening(s), if present, shall be tested as stated in the technical documentation by the manufacturer.
- Further openings, if present, shall be tested as stated in the technical documentation by the manufacturer.

6.4.2 Battery boxes

6.4.2.1 Standard test

The maximum possible energy of batteries on **one** shelf shall be tested. The prepared battery box, maximum *energy (Wh)*, shall be placed on the middle of the shelf positioned in the middle of the cabinet (see Figure 3). If a shelf in the middle is not available in the construction, the shelf closest to the middle shall be used.

Surface (alternatively air) thermocouples shall be positioned next to the triggered battery box (when possible on all sides). Additional surface (alternatively air) thermocouples shall be positioned, one on each of the other shelves.

During the test, the storage levels above and below the tested storage level (if available) shall also be fitted with batteries/cells in order to verify the prevention of propagation. These cells shall be placed in a box with the same footprint (width x depth) as the battery box used for the thermal runaway. To save costs, only one layer of cells lying down may be positioned inside these battery boxes. The additional installation of temperature sensors on the levels above and below the tested storage level is possible (see figure 3).

6.4.2.2 Test without propagation blocking

If it is not possible to prove a prevention of propagation to the upper and/or lower shelf, the maximum possible energy of batteries on all shelves shall be tested. The prepared battery boxes, maximum *energy (Wh / Ah)*, shall be placed on the middle of each shelf (If present). (Figure 4).

Surface (alternatively air) thermocouples shall be positioned next to the triggered battery box (when possible on all sides). Additional surface (alternatively air) thermocouples shall be positioned one the left and right side of each of the other battery boxes.

To raise the propagation of cells, it is permitted to position heating elements also in the other battery boxes. The triggering of the thermal runaway in all the battery boxes must then be initiated within one hour.

6.4.3 Sensors

The minimum number of thermocouples shall be installed inside the cabinet according to figure 3/4, to monitor the temperature throughout the test:

- a) Surface-Thermocouples shall be installed on the centre of each external side wall, the centre of the external back wall and one at the centre of the external top wall of the cabinet to measure the outside temperature of the cabinet (Figure 3 and 4).
- b) Air Thermocouples shall be placed outside the cabinet, in the centre of each gap/joint related to the height and in the middle of the gap, in a distance of $(26 \pm 1,5)$ mm from the gap/joint to measure the escaping gas / smoke temperature (Figure 3 and 4).
- c) Four air thermocouples for measuring the air temperature in the inner corners (upper front right, upper front left, lower front right, lower front left) each $(26,5 \pm 1,5)$ mm from the walls, interior door surface and ceiling/floor.
- d) Pressure blast sensor shall be placed inside the cabinet in the centre of the door to measure the pressure peak during the thermal runaway for reference (Figure 3 and 4).
- e) If there are additional openings additional thermocouples (smoke / gas detection) shall be placed in the area of each opening at a distance of $(26 \pm 1,5)$ mm from the centre of the opening.
- f) If the cabinet is intended for use on wheels or castors, the fire resistance shall be (additionally) determined with this design. This means each version shall be tested separately.
- g) For two door cabinets only, four additional thermocouples for measuring the air temperature are needed. Four at $(26 \pm 1,5)$ mm from the centre door joint, two $(26,5 \pm 1,5)$ mm from the ceiling (one on the outside and one on the inside) and two approximately half-way up the cabinet (one on the outside and one on the inside).
- h) At least one additional thermocouple shall be inside the battery box on the surface of one cell to prove, if the TR has occurred. This cell shall be as far as possible from the heating element.

NOTE For sustainability and reproducibility reasons in the long run and after testing several units it is planned to update this document to a test procedure without any batteries. For this a test procedure with an equivalent is planned to be used.

As currently no sufficient data for such an equivalent is available, this version of the standard aims to additionally collect data to define a realistic equivalent. Therefore, more thermocouples are used than needed to fulfil the test. Also, the pressure measurement is not a criterion to meet the minimum requirements according to 4.3, but is intended collect pressure data for the equivalent.

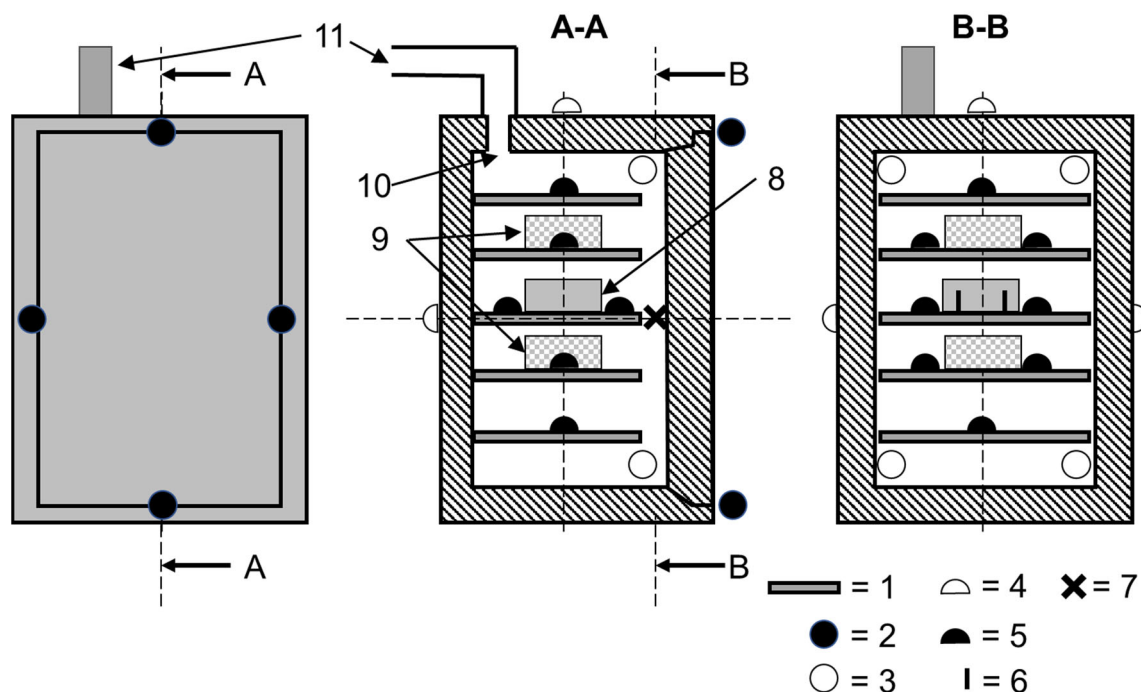


Figure 3 – Preparation of test specimen (standard test)

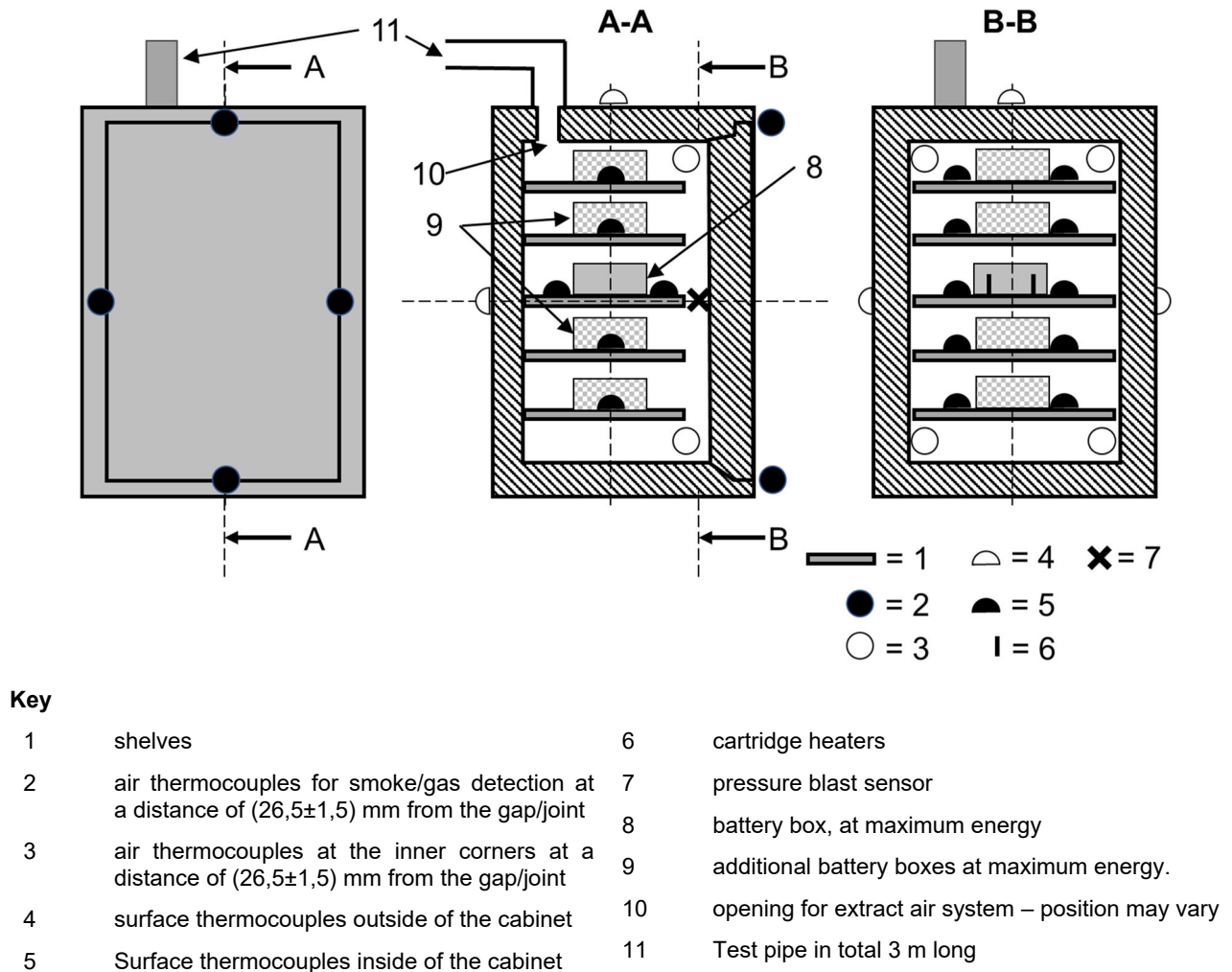


Figure 4 – Preparation of test specimen (without propagation blocking)

6.5 Test (Thermal Runaway)

During the test, the cabinet unit shall be closed and blocked as defined by the manufacturer to fulfil 4.2.3 (for instance if the specimen has a self-locking mechanism the door shall be closed by the mechanism. If it has an alarm system that can only be deactivated if the door is locked, it shall be locked etc.).

- The temperature of the cartridge heaters is continuously increased until the Thermal Runaway is triggered.
- The temperature next to the battery box shall be continuously monitored with the thermocouples next to the battery box (see Figure 3 and 4) until at least 350 °C is reached, to ensure that the Thermal Runaway has been triggered.
- The pressure (data collection) shall be continuously monitored inside the cabinet in the centre of the door to measure the pressure peak during the thermal runaway for reference.

Start of measurement:

- All measurements to control the requirements according to clause 4.3 start when the cartridge heaters are activated.

End of measurement:

- All measurements to control the requirements according to clause 4.3 stop if the internal temperature of the cabinet has dropped to 50°C for more than 120 minutes or

- if the requirements of clause 4.3 have not been reached and the internal temperature of the cabinet has dropped to 50°C for more than 120 minutes and no further findings are expected, the test shall be stopped.
- After completion of the test, it shall be checked how many of the cells have been triggered. The proof if the TR has been initiated shall be made optically.
- The permissible amount of stored energy per shelf corresponds to the amount of energy that went into the thermal runaway during the test.
- Additionally, it shall be checked, if the propagation to other shelves has been prevented. This shall be performed optically, by checking how many of the batteries/cells above and/or under the tested battery have been triggered.
- If propagation to the batteries above and/or below the tested battery is not prevented during the test, the manufacturer shall either
 - retest under the same conditions with an optimized shelf/storage level or
 - retest with battery boxes on each shelf with their maximum energy permitted per shelf (see Figure 4). The maximum permissible stored energy in the cabinet in series production is then the energy of the triggered cells plus 10 %. If additionally heating elements were positioned in the other battery boxes, the maximum permissible energy in the cabinet, is the energy of all triggered cells.

The test is passed if all requirements for the TR test according to clause 4.3 are fulfilled.

7 Test methods (fire from outside)

7.1 General requirement

The test shall be performed by a testing laboratory, which is experienced in the area of testing cabinets.

The fire endurance of the cabinet test specimen is assessed by heating in a furnace.

During the type test the temperature in the interior of the cabinet test specimen is measured.

7.2 Test equipment

7.2.1 Test environment/test room

The laboratory determines the test environment considering the risk. The laboratory is also responsible for the necessary safety measures regarding firefighting.

The furnace shall be arranged so that the doors, walls and roof of the tested cabinet receive equal heat conditions, without flames directly touching the cabinet body.

The distance between the interior walls of the furnace and the surface of the test specimen shall be according to Figure 6. The furnace conditions shall conform to EN 1363-1:2020. To meet these conditions, the setting of the neutral pressure level shall be made in accordance with 7.2.2 and the measurement of the temperature in the interior of the furnace shall be made with instrumentation in accordance with 7.2.3.

7.2.2 Pressure and heating conditions

The furnace shall be operated such that the neutral pressure level is reached after 5 min of firing, measured at ± 5 Pa 1 000 mm above the furnace base. The use of a base below the cabinet is permitted. For pressure measurements, pressure measuring heads in accordance with 4.5.2 of EN 1363-1:2020 shall be used.

If using a plinth: In order to ensure consistent heating conditions the width of the plinth area around the projected cross-sectional area of the test specimen shall not exceed 200 mm.

7.2.3 Thermocouples for the furnace temperature

Thermocouples of type K (NiCr-Ni) with a measurement uncertainty in accordance with EN 60584-1 for measuring the furnace temperature shall be used. The furnace thermocouples shall be plate thermometers according to 4.5.1.1 of EN 1363-1:2020.

7.2.4 Thermocouples inside the test specimen

Thermocouples consisting of 0,5 mm diameter wires of type K (NiCr-Ni) or type J (Fe-CuNi) with a measurement uncertainty in accordance with EN 60584-1 for measuring the air and surface temperatures in the test specimen. The measurement results shall be recorded at intervals not greater than 1 min. The contact measurement points shall be assembled in accordance with 4.5.1.2 and 4.5.1.4 of EN 1363-1:2020, respectively.

7.2.5 Timing device

A timing device, capable of running continuously throughout the test period shall be used.

7.2.6 Equipment for weighing test specimens.

Equipment for weighing test specimens, with an uncertainty of measurement of $\pm 3 \%$ shall be used.

7.2.7 Preparation of the test

Suitably modify the base of the test specimen for the fire endurance test to allow the entry of thermocouple cables. Plinths and other elements that may prevent proper protection of the thermocouple cables may be removed.

All openings shall be prepared and tested as stated in the technical documentation by the manufacturer:

- If cable entries are available, then the opening(s) shall be included in the test specimen and the cable routing shall be sealed (if provided) according to the manufacturer's specifications.
- If anchoring holes are available, then the holes shall be included in the test specimen.
If a closure of the opening is provided, then the holes shall be closed according to the manufacturer's specifications.
- The connection part to the extract air system shall be included in the test specimen.
- Ventilation opening(s), if present, shall be tested as stated in the technical documentation by the manufacturer.
- Further openings, if present, shall be tested as stated in the technical documentation by the manufacturer.

For the fire endurance test (see 7.2.8) install thermocouples at the following measuring points in the test specimen (see 7.2.4) to enable temperature measurement:

- a) Four thermocouples for measuring the air temperature in the upper corners each $(26,5 \pm 1,5)$ mm from the walls, interior door surface and ceiling (see Figure 5).
- b) One thermocouple for measuring the surface temperature on each of the ceiling, side walls, rear wall, and door, approximately in the centre of each surface (see Figure 5).
- c) For two door cabinets only, two additional thermocouples for measuring the air temperature at $(26,5 \pm 1,5)$ mm from the centre door joint, one $(26,5 \pm 1,5)$ mm from the ceiling and the other approximately half-way up the cabinet.
- d) Additional surface thermocouples $(26,5 \pm 1,5)$ mm next to openings and in case of elements reaching from outside into the cabinet, $(26,5 \pm 1,5)$ mm on these elements, $(26,5 \pm 1,5)$ mm away from the inner wall.
- e) If the cabinet is intended for use on wheels or castors, the fire resistance shall be (additionally) determined with this design. This means each version shall be tested separately.

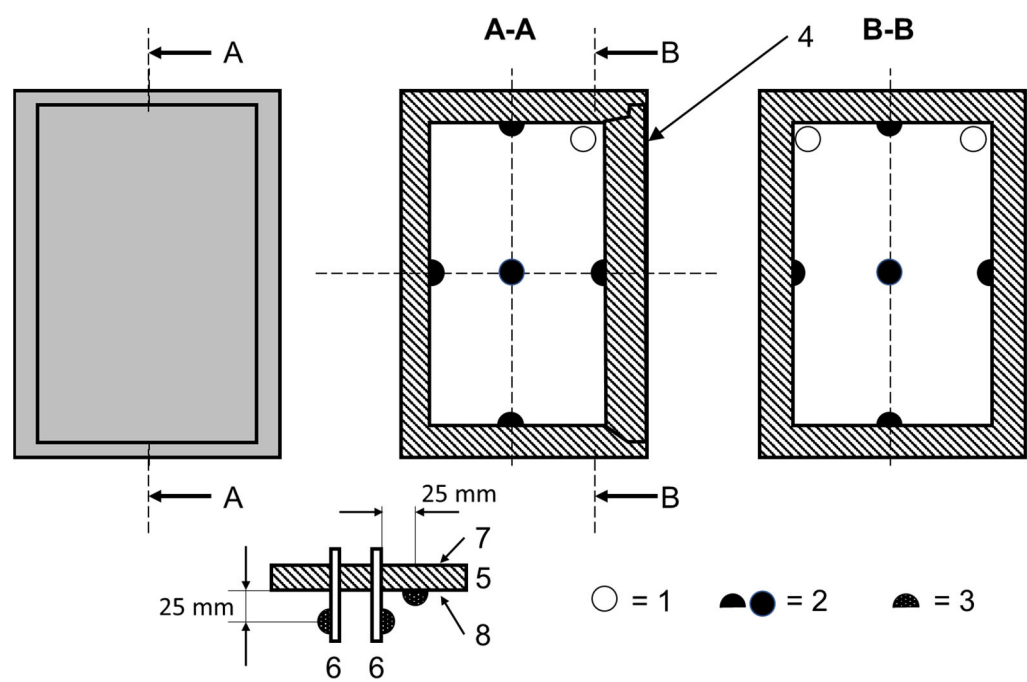
After all instrumentation has been installed maintain the test specimens in a controlled climate of temperature $(23 \pm 2)^{\circ}\text{C}$ and relative humidity $(50 \pm 5) \%$ for a minimum of 16 h prior to the beginning of the type test. All compartments or drawers of the test specimens shall be open during the conditioning period.

Close all doors and compartments (e.g. drawers) prior to removing the cabinet from the controlled environment and commence testing within 1 h.

Install the instrumentation for measuring the furnace temperature (see 7.2.3) in the furnace (see 7.2.1) at four measuring points. Locate the measuring points

- (100 ± 5) mm from three of the walls as well as the ceiling of the test specimen

- (50 ± 5) mm from back walls of the test specimen (only for orientation) and approximately in the centre of the vertical surfaces of the test specimen.
- The temperature of the furnace immediately prior to ignition shall be (20 ± 10)°C.



Key			
1	air thermocouples a distance of (26,5±1,5) mm from the walls, interior door surface and ceiling	4	door
2	surface thermocouples on each of the ceiling, side walls, rear wall, and door, approximately in the centre of each surface	5	section cabinet ceiling, backwall or sidewall, penetration
3	surface thermocouples penetration	6	pipe, cable or hoses
		7	fire side (furnace)
		8	fire-retardant side (inside cabinet)

Figure 5 – Preparation of test specimen for the outside test

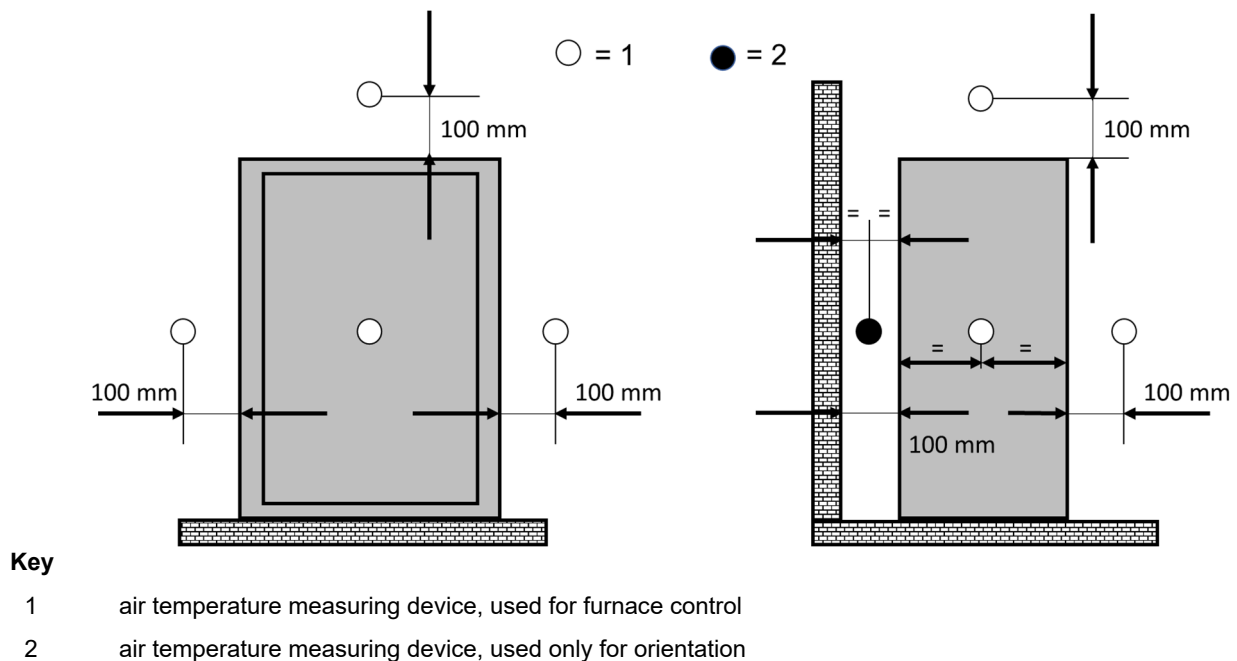


Figure 6 – Positions for temperature measuring devices inside furnace

7.2.8 Test

Expose the test specimen to the furnace flames and maintain the mean furnace temperature in accordance with the time-temperature curve in accordance with EN 1363-1:2020 for 30 min, 60 min or 90 min as required for the appropriate class (see Clause 4.1).

The temperature measurement can end when the burners are switched off.

Record the temperature increase at all measuring points (see Figure 5).

NOTE Observations can be made during the type test. They can be recorded and photographed.

The test is passed if all requirements for the outside test according of clause 4.3 are fulfilled.

After type testing remove, examine and compare samples of the test specimen with the technical documentation and material samples provided for the type test. Observations of the unit's post-test condition, such as the weight and material condition, shall be recorded.

Make a photographic record of the following construction details: The outside of the tested specimen, the plinth of the test specimen (if available), the areas where samples have been removed and the interior of the test specimen.

8 Test report

The test report shall contain the following information:

- a) Number and/or title of this document.
- b) Name of testing laboratory.
- c) Unique identification number to the test report.
- d) Date(s) and location of the type testing (e.g., town, country);
- e) Name of the manufacturer, place and year of manufacture of the cabinet test specimens and product name of the cabinet test specimens.
- f) Weight of the cabinet test specimen.
- g) Type and total energy of tested cells.

- h) One copy of the technical documentation including all associated dimensions, construction materials, seals, etc. of the cabinet test specimen.
- i) Details of the location of the measuring points.
- j) Details of temperature recordings made before and during the type test.
- k) Relevant observations recorded before, during and after the test procedure.
- l) Number of cells in which the TR occurred during the inside test and the resulting maximum energy for series production.
- m) Number of cells positioned above and below the TR cells and if a propagation has happened.
- n) Description of the specimen after the type test including the condition and operability of locks and boltwork.
- o) Photographs taken before, during and after the type test.
- p) Results of the moisture test of the insulating material.
- q) Note on the ease of opening the door of the test sample after type testing.
- r) Note on the stability of the shelves during the heating process, as far as information on this is available.
- s) The report should contain a statement that the results obtained relate only to the sample tested and should be regarded as only the basis for certification.
- t) The report itself should not be considered to be a Certificate of Conformance.

9 Marking

Each lithium-ion battery storage cabinet shall be legibly and permanently marked in a suitable location on the inside of the cabinet door.

The marking shall comprise at least the following:

- a) identification of the manufacturer;
- b) serial number and year of manufacture;
- c) weight of the product;
- d) number of this VDMA Specification, including the class (I, I/O30, I/O60 or I/O90).

Furthermore, each lithium-ion battery storage cabinet shall be legibly and permanently marked on the outside of the cabinet with the following information:

- a) indication that the cabinet is used for storage of lithium-ion batteries together with the sign W001 of EN ISO 7010.
- b) indication that the doors shall be kept closed;
- c) Warning symbol "Caution risk of fire" and the respective prohibition symbol;
- d) warning that in the event of a fire and/or if an alarm notice from the cabinet is triggered, unlocking should only be performed by an authorized professional with appropriate personal protective equipment;
- e) maximum energy of the batteries to be stored (Wh) on each shelf and of the entire cabinet;
- f) maximum load capacity of each shelf and of the entire cabinet;
- g) warning that lithium-ion batteries have a risk of producing toxic and flammable gases, it is therefore highly recommended to connect the cabinet to a suitable extract air system;
- h) there shall be a notice that the cabinet shall not be placed near fire loads.