GUIDE BATTERY STORAGE · 18 MIN

Thermal Barriers in Battery Energy Storage: Refractory Materials Against Thermal Runaway

How planners and operators of battery energy storage systems (BESS) limit thermal propagation between cell, module, rack and container — codes and standards, material selection, installation, testing and maintenance from a refractory contractor's perspective.

What Happens During Thermal Runaway — and Why Time Is the Decisive Factor

A thermal runaway begins in a single cell: an internal short circuit, mechanical damage, overcharging or a manufacturing defect raises the cell temperature to the point where the decomposition of the electrolyte becomes self-accelerating. Within seconds, several hundred degrees Celsius are reached, along with flammable gases (hydrogen, carbon monoxide, hydrocarbons) and a jet of hot particles. The cell itself cannot be extinguished in this state — the reaction runs until the stored energy is consumed.

What endangers the installation is not the single cell but propagation: the heat from the first cell warms the neighbouring cells until the threshold is exceeded there as well. Without barriers, the chain runs through the module, the rack and finally the container. Every stage that delays transmission by minutes buys the battery management system time to shut down, the gas venting system time to exhaust, and the fire brigade time to arrive.

Note: The Core Task of Refractory Materials — Not to extinguish, but to separate: a thermal barrier between the levels keeps the temperature on the unexposed side below the ignition threshold of the neighbouring cells long enough for propagation to stop or slow to a manageable rate. The benchmark is the time to temperature breakthrough — not the classification temperature of the material alone.

- Cell level: temperatures at the cell surface above 600 °C, particle jet exceeding 1000 °C
- Module level: gas release of several hundred litres per kWh, pressure build-up inside the enclosure
- Rack and container level: fire load from plastics, cables and electronics is added
- Time window: propagation between adjacent cells without a barrier typically within minutes, with an effective barrier significantly delayed or interrupted

Codes and Standards: What Is Required and What Must Be Demonstrated

In Germany there is no single, definitive law for stationary battery energy storage — the requirements are assembled from product standards, test methods, insurers' guidelines and building regulations. For material selection inside the container, the decisive elements are above all the test methods by which resistance to propagation is demonstrated.

UL 9540A is the internationally established test method that examines the spread of a thermal runaway in stages at cell, module, unit and installation level. Many tender specifications and insurers now demand a UL 9540A report; the temperatures and times documented in it are the input values for designing the thermal barriers. NFPA 855, as the installation standard, governs separation distances, fire compartments, and suppression and venting concepts. In Europe, IEC 62933-5-2 describes the safety requirements for grid-connected electrochemical storage systems. The VdS 3103 guideline summarises the expectations of German property insurers regarding lithium-ion storage systems.

For the refractory materials themselves, the classifications under DIN EN 13501-1 (reaction to fire, Class A1 for non-combustible products) and the fire resistance tests under DIN EN 1363 and DIN EN 1364 apply. For fibre materials, occupational safety comes on top: alumino-silicate wool (ASW) falls under TRGS 558, bio-soluble AES wool does not — a point that almost always tips the balance in battery storage applications.

Note: Practical Advice — Ask the system supplier for the UL 9540A report at module and unit level before discussing materials. The surface temperatures measured there and the duration of the event determine what barrier performance you need — anything else is designing in the dark.

The Barrier Concept: Four Levels, Four Tasks

An effective barrier concept follows the structure of the storage system from the inside out. Each level has its own task, its own temperature load and therefore its own appropriate material. Anyone who installs the same material at every level either pays too much or provides too little protection at the critical point.

- Cell to cell: thin interlayers of 1 to 3 mm that delay heat transfer to the neighbouring cell — ceramic fibre paper in bio-soluble quality or microporous film laminates; what matters is low thickness combined with low thermal conductivity at high temperature
- Module to module: boards of 5 to 25 mm between the modules in the rack — microporous boards with the highest insulating performance per millimetre where installation space is tight; calcium silicate boards where compressive strength is also needed
- Rack to rack and rack to wall: partition walls and linings with fire resistance — calcium silicate or fibre boards in layers, joints staggered, connections sealed with fibre rope
- Container internal lining: wall and ceiling lining of bio-soluble fibre blanket or board that keeps the steel shell below the critical temperature and prevents fire spread to neighbouring containers

Then there are the penetrations: cables, cooling lines, busbars and ventilation openings pass through every level. A partition wall is only as good as its weakest penetration — here, fibre ropes, paper gaskets and fire collars become part of the concept, not accessories.

Material Selection: Bio-Soluble, Microporous, Fibre-Free — and Why ASW Is Rarely the Right Answer in Battery Storage

In an industrial furnace, temperature dictates the material. In battery storage, three additional requirements shape the selection more strongly: installation space, occupational safety and the customer's bill of materials.

Bio-soluble AES wool (SOLUT BW Blanket, BW Board, BW Paper) is exempt from classification as carcinogenic under Note Q of the CLP Regulation and does not fall under TRGS 558. For storage system manufacturers this means: no exposure categories during installation, no labelling obligation in the product, no SVHC notification under REACH Art. 33. With a classification temperature of 1200 °C it covers the temperatures occurring at wall and ceiling during a thermal runaway. Its practical continuous-service limit below roughly 900 °C is irrelevant here — the load case is an event lasting minutes, not continuous operation.

Microporous boards (SOLUT MP Board) offer the lowest thermal conductivity of all insulating materials — around 0,02 to 0,03 W/mK at 200 to 400 °C — and thus the greatest barrier performance per millimetre. That makes them the material of choice between modules, where every millimetre of installation space costs energy density. They are fibre-free, non-combustible (A1) and available faced with aluminium foil, glass cloth or PE film so that they do not release dust during handling.

Calcium silicate boards (SOLUT CAL Board) go where the barrier has to carry load: beneath racks, as partition walls with fixings, as bases for components. Compressive strengths of 13 to 27 N/mm² at a classification temperature of 1000 °C, fibre-free and workable with woodworking tools.

Note: Why Not ASW? — Alumino-silicate wool does withstand 1260 to 1430 °C, but is classified as a Category 1B carcinogen. In a product that manufacturers ship to many countries and that service technicians open, this entails labelling, information and occupational safety obligations that hardly any storage manufacturer wants to bear. The temperature reserve of ASW is not needed in battery storage — the bio-soluble alternative is sufficient for the load case.

- Cell interlayers: SOLUT BW Paper 1–3 mm or microporous laminate
- Module separation: SOLUT MP Board 5–25 mm, faced
- Load-bearing partition walls and bases: SOLUT CAL Board 12,7–50 mm
- Container wall and ceiling lining: SOLUT BW Blanket 25–50 mm or BW Board
- Penetrations and joints: fibre rope and BW Paper, combined with approved penetration sealing systems at fire compartment boundaries

Material Comparison: The Four Barrier Materials at a Glance

The following overview compares the four most important barrier materials — with the properties that really matter in battery storage: thermal conductivity in the event case, installation space requirement, mechanical load capacity and regulatory status.

Note: Rule of Thumb — Where installation space is the scarcest resource: microporous. Where load is carried or fixings are screwed: calcium silicate. Where surfaces are lined: bio-soluble fibre. Where it has to be thin: fibre paper. ASW only where insulation is permanently above 900 °C — in battery storage, practically never.

Installation and Testing: Where the Barrier Fails in Practice

The best material selection is worthless if the barrier has gaps. From our installations we know four recurring weak points: open butt joints between boards, unsealed penetrations, steel fixings that act as thermal bridges through the insulation, and insulation layers that are crushed during assembly and thereby lose their thickness and insulating performance.

- Stagger board joints in two layers or use tongue-and-groove joints; back single-layer butt joints with fibre rope
- Draw every penetration as its own detail: rope, paper or collar, with a sealing length at least equal to the board thickness
- Thermally decouple fixings — ceramic or stainless steel anchors with washers instead of continuous steel screws
- Check insulation thickness in the installed condition, not as delivered; document clamping and compression
- Assess facings and films on the side exposed to the event: they protect during handling but contribute nothing in a fire

Verification is carried out in two stages: the material properties come from the data sheets and the fire classifications, and the barrier performance of the system from a propagation test at module or unit level — sensibly in accordance with UL 9540A, because the results are then also usable for insurers and approval authorities. We supply the material data and support the manufacture of test specimens so that the tested system matches what is installed later.

Planning Checklist: What Must Be Clarified Before Tender and Quotation

Most delays in storage projects arise not during installation but before it — because the fundamentals are missing when quotations are to be compared. These twelve points should be clarified before the first enquiry goes out:

- UL 9540A reports from the cell/module supplier available at module and unit level? What temperatures and times were measured?
- Protection objective defined: prevent cell-to-cell propagation, delay module-to-module, or only separate container from container?
- Installation space budget set for each level (mm between cells, modules, racks)?
- Insurer's requirements obtained (VdS 3103, plus any specific conditions)?
- Reaction to fire of the materials specified as Class A1 to DIN EN 13501-1?
- Fibre-free bill of materials required — or is bio-soluble fibre (Note Q) permissible?
- Penetrations counted and a sealing detail defined for each type (cable, cooling line, busbar, ventilation)?
- Fixing concept planned without continuous thermal bridges?
- Compression of the insulation layers during assembly calculated — thickness in the installed condition?
- Test specimens for the propagation test scheduled (material, date, test institute)?
- Series production: cutting supplied as a kit or as individual parts? Tolerances defined?
- Dismantling and spare parts concept: how is a barrier reinstated after a maintenance intervention?

Note: Our Offer to Planners — Send us the UL 9540A data and the installation space budget — we will propose the layer build-up for each level, supply the material properties for the safety verification and, on request, manufacture test specimens and series kits.

Operation, Maintenance and Dismantling

A thermal barrier does not work in normal operation — it waits. Which is exactly why it is easily damaged during maintenance and modification: boards are removed for access and reinstated incompletely, seals at penetrations are lost during cable replacement, insulation layers are crushed by retrofitted components. The maintenance documentation should therefore include a barrier plan that identifies every barrier, every penetration and every seal.

- After every intervention: visual inspection of the affected barrier against the barrier plan, photo on file
- Annually: spot checks of the penetration seals and the compression of the insulation layers
- After a thermal event: completely replace the affected barriers — bio-soluble wool and microporous boards also lose their properties after a temperature breakthrough
- On removal: separate materials according to their labelling — bio-soluble and fibre-free materials are not hazardous waste, while used ASW falls under waste code 170603*

Note: From a Single Source — We supply the materials with data sheets in seven languages, cut boards and blankets to drawing, install with our own fitters and, in the event of modification or decommissioning, handle the dismantling including proof of disposal. For manufacturers producing storage systems in series, we prefabricate barrier kits.

Standards and regulations

UL 9540A
Test method for evaluating thermal runaway propagation at cell, module, unit and installation level (Provides temperatures and times for barrier design; increasingly demanded by insurers and tender specifications)

NFPA 855
Installation standard for stationary energy storage systems — separation distances, fire compartments, suppression and venting concepts (Framework for the arrangement of partition walls and distances between units)

IEC 62933-5-2
Safety requirements for grid-connected electrochemical energy storage systems (European basis for safety verification of the overall system)

VdS 3103
Guideline of the German property insurers for lithium-ion batteries and storage systems (Insurers' expectations regarding siting, thermal barriers and fire protection)

DIN EN 13501-1
Classification of the reaction to fire of construction products (Class A1: non-combustible) (Verification of the non-combustibility of the insulating and partition materials used)

DIN EN 1363-1 / EN 1364
Fire resistance tests, general requirements and non-loadbearing elements (Verification of the fire resistance of partition walls and linings)

TRGS 558
Activities involving high-temperature wool — exposure categories and protective measures (Applies to ASW, not to bio-soluble AES wool; decisive for material selection)

CLP Regulation, Note Q
Exemption of bio-soluble mineral wools from classification as carcinogenic (Basis for fibre materials in battery storage that require no labelling)

Frequently asked questions

Is bio-soluble wool rated at 1200 °C sufficient when a thermal runaway exceeds 1000 °C?

For this load case, yes: the classification temperature describes shrinkage after 24 hours of continuous exposure. A thermal runaway is an event lasting minutes, during which the barrier must delay heat, not endure it permanently. What matters is the thickness and the thermal conductivity — and verification on the tested system.

Why microporous instead of simply a thicker fibre blanket?

Because installation space in a storage system is energy density. A microporous board achieves with 10 mm what fibre blanket needs two to three times as much thickness for. Between modules, that is the difference between one rack more or less in the container.

Do the materials themselves need an approval?

The materials need classifications (reaction to fire A1, data sheet values). The approval concerns the system: resistance to propagation is tested on the module or unit, not on the material alone. We supply the material data for this verification.

What happens to the barriers after an event?

Affected barriers are completely replaced. Insulating materials that have experienced a temperature breakthrough are embrittled or compacted and no longer achieve their rated properties — even if they appear intact from the outside.

Let us talk about your project

Reply within 24 hours on working days.

info@sbs-rs.de

+49 89 541 960 200

Read online: www.sbs-rs.de/batteriespeicher/ratgeber/thermische-abschottung-batteriespeicher