BAM
Bundesanstalt für Materialforschung und -prüfung

# Annex 1 to BAM-GGR 024

# Assessment of non-reactive or partially reactive cells/modules/batteries



## General information

For a successful fire test in accordance with Annex 2, all cells must have gone into thermal runaway (TR). However, due to the enhancements of cells/modules/batteries in terms of safety technology, there are also cells/modules/batteries for which a complete TR cannot be realised. These are referred to here as non-reactive or partially reactive cells/modules/batteries.

Assessments and fire tests that were carried out before this GGR came into force remain valid until the associated specification expires.

Cells that cannot be forced into thermal runaway using the test procedures listed below are not classified by BAM as critically defective within the meaning of special provision 376 and packing instructions P 911 and LP 906. Therefore, this part of the special provision 376 and the packing instructions P 911 and LP 906 and accordingly this BAM-GGR do not apply.

Discharged cells/modules/batteries are not classified by BAM as critically defective within the meaning of special provision 376 and packing instructions P 911 and LP 906. Therefore, this part of the special provision 376 and the packing instructions P 911 and LP 906 and accordingly this BAM-GGR do not apply.
Proof is deemed to have been provided when the cells/modules/batteries have been discharged to the final discharge voltage in accordance with the manufacturer's specifications.

To determine the TR behaviour of these cells/modules/batteries, proceed as follows:

1) Test the individual cell for TR (see section 2.)
2) If the individual cell shows a TR, propagation tests must be carried out.
    a) Propagation test on cells (see section 3.1.)
    and/or
    b) Propagation test in the module (see section 3.2)
    and/or
    c) Propagation test in the battery (see section 3.3)

The application of this annex is optional; parts of this annex may be applied if necessary.

## 1. Definition of TR (thermal runaway)

A cell is reactive when a TR occurs. A TR occurs when a temperature change of 23 °C takes place in less than 20 seconds. The temperature difference of 23 °C is the reference value, while the time required is the evaluation criterion. The temperature-time trend below 77 °C can be ignored in the evaluation.

## 2. Testing the individual cell for TR

Proof that the cell shows no TR in the event of damage can be provided by the following tests on an individual cell. The cell must not be installed in a module/battery for this purpose. The test can take place outside of a transport packaging. Each test must be performed three times (on three different cells). The temperature of the cell during the test must be at least 10 °C.

1. Penetration test

   The mechanical damage in the penetration test can be realised by one of the following two methods:

| | Diameter | Shape of the tip | Feed rate | Penetration depth into the cell | The material |
|---|---|---|---|---|---|
| Nail | ≥ 6mm | Truncated cone with an angle of 60°Tip flattened with a diameter of ≥ 2.5 mm | ≥ 40 mm/s | ≥ 50 % | electrically conductive |
| Drill bit | ≥ 6mm | HSS/HSSE twist drill according to DIN 338, 340, 341, 345, 1897 or 1870 | ≥ 1 mm/s | ≥ 50 % | electrically conductive |

   If a TR occurs due to penetration, the cell must be assessed as reactive.

2. Overcharging

   Overcharging must be carried out with a CCCV charge. A voltage source with at least 10 V must be used for this. The charge is carried out with at least 1 C. The final charging voltage is 10 V. If a TR occurs during overcharging, the cell must be assessed as reactive.

3. Thermal damage

   Thermal damage must be carried out with a heating rate of 10 K/min. The cell must withstand a temperature of 350 °C for 30 min. If a TR occurs during heating or within the 30 min, the cell must be assessed as reactive.

Suitable measurement methods must be used to assess the TR (e.g. temperature recording, video recording).

## 3. Propagation test to determine the transport conditions

### 3.1. Propagation test on cells

To determine whether there is propagation from cell to cell, at least four cells must be grouped together to form a fixed package, which is bounded on all sides by a heat-insulating plate.
There must be no insulating material between the cells. The poles of the cells should all be aligned in the same direction.
An outer cell must be initiated using a suitable method. It must be ensured that the initiated cell enters the TR.
This test must be performed three times
This test can be performed outside a packaging.
Suitable measurement methods must be used to assess the TR and propagation (e.g. temperature recording, video recording).

**Assessment:**

a) If propagation takes place from the first to the fourth cell, a further propagation test can be carried out in accordance with 3.2 and/or 3.3 and/or 3.4. These tests are necessary because the transport conditions are determined based on the propagation behaviour.
Alternatively, a fire test according to Annex 2 can be carried out.

b) If the TR does not progress to the fourth cell, this is not categorised as propagation.
If no propagation takes place, these cells or modules and batteries made of these cells may be transported if the selected packaging has passed a fire test in accordance with Annex 2 of this BAM-GGR. The fire test may be performed with cells or modules or batteries composed of these cells of any level according to Annex 3 of this BAM-GGR, but at least with the nominal energy to be transported.

### 3.2. Propagation test on modules (with safety devices)

To determine whether propagation occurs from cell to cell within a module, one cell must be initiated on each of at least three modules using a suitable method. It must be ensured that the initiated cells go into the TR.
The test can be performed outside a packaging.
Suitable measurement methods must be used to assess the TR and propagation (e.g. temperature recording, video recording).

**Assessment:**

a) There is no propagation (from cell to cell within a module):[1]
These modules and batteries made of these modules may be transported if the selected packaging has passed a fire test in accordance with Annex 2 of the BAM-GGR. The fire test may have been carried out with modules or batteries of any level in accordance with Annex 3 of this BAM-GGR, but at least with the nominal energy to be transported.

[1] Due to the safety devices, the conditions for propagation according to section 3.1 do not apply.

b) Partial propagation takes place (propagation from cell to cell, but not through the entire module):
These modules and batteries made of these modules may be transported if the selected packaging has passed a fire test in accordance with Annex 2 of the BAM-GGR. The fire test must have been carried out with modules or batteries of at least the same level in accordance with Annex 3 of the BAM-GGR, and at least with the nominal energy to be transported.

c) Complete propagation takes place (propagation throughout the entire module):
These modules and batteries made out of these modules may be transported if a fire test in accordance with Annex 2 of the BAM-GGR has been carried out with the modules to be transported or batteries made out of these modules.
In addition, the 80% rule, Annex 3, can be applied if the fire test was carried out with other modules or batteries.

## 3.3. Propagation test on batteries (with safety devices) made of modules

To determine whether propagation occurs from module to module, at least three points (three modules) must be initiated using a suitable method. It must be ensured that the initiated cells enter the TR.
The test can be performed outside a packaging.
Suitable measurement methods must be used to assess the TR and propagation (e.g. temperature recording, video recording).

**Assessment:**

a) There is no propagation between modules (regardless of whether the initiated module propagates completely, or the process comes to a standstill beforehand):
These batteries may be transported if the selected packaging has passed a fire test in accordance with Annex 2 of the BAM-GGR. The fire test may have been carried out with modules or batteries of any level in accordance with Annex 3 of the BAM-GGR, but at least with the nominal energy of the battery to be transported.

b) Partial propagation takes place (propagation between modules, but not through the entire battery):
These batteries may be transported if the selected packaging has passed a fire test in accordance with Annex 2 of the BAM-GGR. The fire test must have been carried out with modules or batteries of at least the same level in accordance with Annex 3 of the BAM-GGR, and at least with the nominal energy of the battery to be transported.

c) A complete propagation takes place:
These batteries may be transported if a fire test in accordance with Annex 2 of the BAM-GGR has been carried out with the batteries to be transported.
In addition, the 80% rule, Annex 3, can be applied if the fire test was carried out with other modules or batteries.

## 3.4. Propagation test on batteries (with safety devices) that are constructed in a cell-to-pack manner

To determine whether cell-to-cell propagation occurs within the battery, at least three points (three non-contiguous cells of the battery) shall be initiated using a suitable method. It must be ensured that the initiated cells go into the TR.
The test can be carried out outside a packaging.
Suitable measurement methods shall be used to assess the TR and propagation (e.g. temperature recording, video recording).

**Assessment:**

a) There is no propagation (from cell to cell):[2]
These batteries may be transported if the selected packaging has passed a fire test in accordance with Annex 2 of the BAM-GGR. The fire test may have been carried out with modules or batteries of any level in accordance with Annex 3 of the BAM-GGR, but at least with the nominal energy of the battery to be transported.

b) Partial propagation takes place (propagation between cells, but this comes to a standstill; the entire battery does not propagate):
Batteries may be transported if the selected packaging has passed a fire test in accordance with Annex 2 of the BAM-GGR. The fire test must have been carried out with modules or batteries of the same level in accordance with Annex 3 of the BAM-GGR, and at least with the nominal energy of the battery to be transported.

c) Full propagation takes place:
These batteries may be transported if a fire test in accordance with Annex 2 of the BAM-GGR has been carried out with the batteries to be transported.
In addition, the 80% rule, Annex 3, can be applied if the fire test was carried out with other modules or batteries.



[2] Due to the safety devices, the conditions for propagation according to section 3.1 do not apply.

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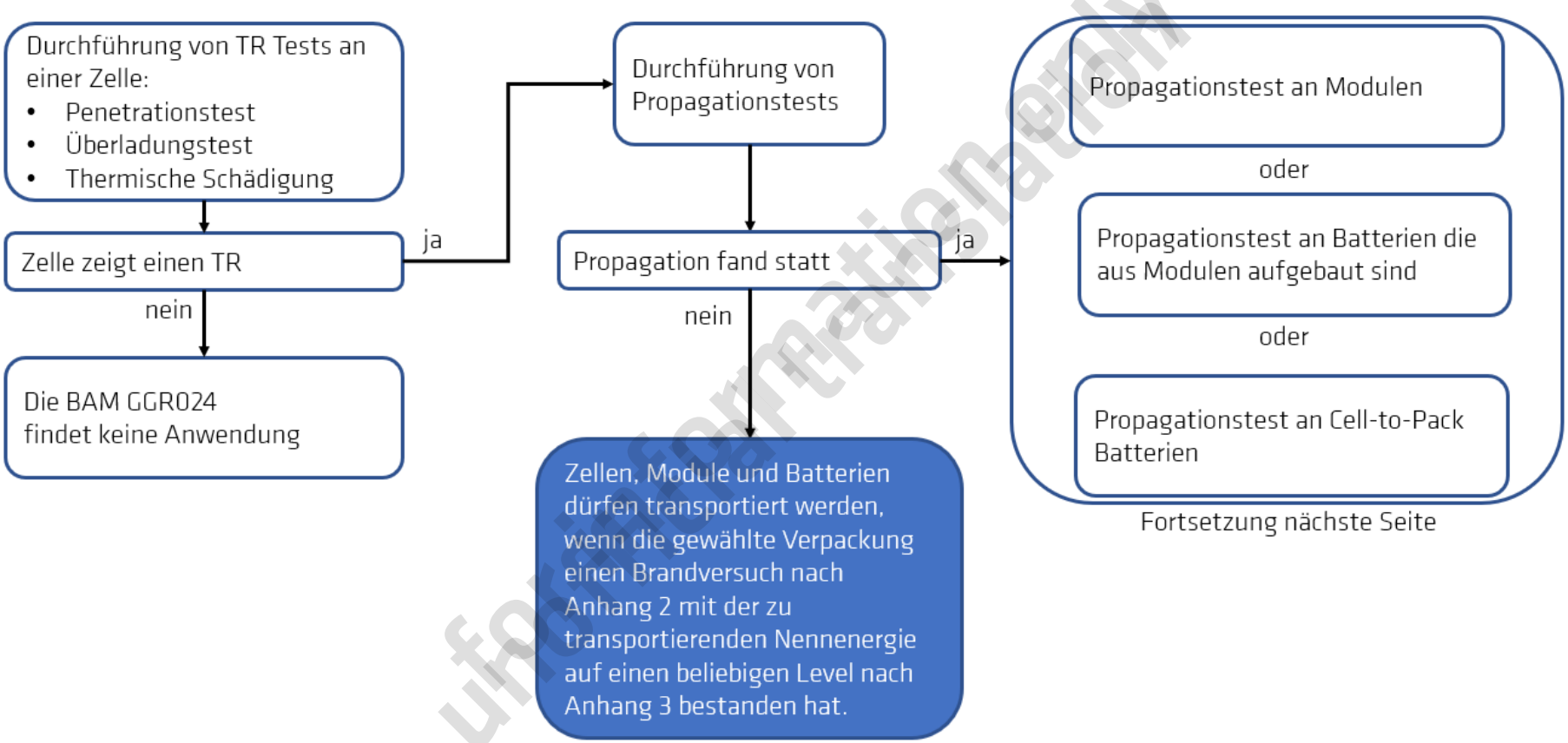
## Decision tree for the performance of propagation tests



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Decision tree continued

| Test result | Propagation test on modules | Propagation test on batteries made up of modules | Propagation test on cell-to-pack batteries |
|---|---|---|---|
| No propagation takes place | **Modules and batteries** from these modules may be transported if the packaging has passed a fire test in accordance with Annex 2 with **at least** the **nominal energy** to be transported of **any level** in accordance with Annex 3. | **Batteries** may be transported if the packaging has passed a fire test in accordance with Annex 2 with **at least** the **nominal energy** to be transported of **any level** in accordance with Annex 3. | **Batteries** may be transported if the packaging has passed a fire test in accordance with Annex 2 with **at least** the **nominal energy** to be transported of **any level** in accordance with Annex 3. |
| A partial propagation takes place | **Modules and batteries** from these modules may be transported if the packaging has passed a fire test in accordance with Annex 2 with **at least** the **nominal energy of the same level** to be transported in accordance with Annex 3. | **Batteries** may be transported if the packaging has passed a fire test in accordance with Annex 2 with **at least the nominal energy of the same** level to be transported in accordance with Annex 3. | **Batteries** may be transported if the packaging has passed a fire test in accordance with Annex 2 with **at least the nominal energy of the same** level to be transported in accordance with Annex 3. |
| A complete propagation takes place | **Modules and batteries** from these modules may be transported if the packaging has passed a fire test in accordance with Annex 2 with the **modules and batteries to be transported** or if these are covered by the 80% rule of other tests | **Batteries** may be transported if the packaging has passed a fire test in accordance with Annex 2 with the **batteries to be transported** or if they are covered by the 80% rule of other tests | **Batteries** may be transported if the packaging has passed a fire test in accordance with Annex 2 with the **batteries to be transported** or if they are covered by the 80% rule of other tests |