TC22 SC37 WG3 Liaison Report for EVS-GTR Thermal Propagation Work Item

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Timeline of ISO 6469-1 AM1

- ❑ 36 months project: Official start 2019-07
- ❑ DIS ballot voting closed 15 July 2021
- ❑ Project on time and projected to be finalized by April 2022

ISO 6469-1 AM1 content and scope

❑ Content

- Safety management for thermal propagation of Li ion based RESS
  - **Primarily provides a tool kit for vehicle and RESS manufacturers to evaluate their product safety in terms of thermal propagation**
  - **Should enable RESS and/or vehicle manufacturers to get a deeper knowledge of the system behaviour in case of an internal failure of a single cell**
  - **It does not contain neither pass or fail criteria for thermal propagation**
  - **It is not foreseen to be used for homologation purposes**

❑ Scope

- Specifies demonstration methods for thermal runaway risk mitigation in case of a cell failure leading to an internal short circuit, including the collection of associated data
  - **Systematic work process to develop a Safety Case for Thermal Propagation of the RESS**
- Specifies a selection of different test methods for thermal propagation
  - **Internal heater**
  - **Localized rapid external heater**
  - **Nail penetration**
- Tests can be performed on vehicle level or on RESS or RESS subsystem level, if appropriate

Guidance for test method and target cell selection

❑ Guidance for method selection

❑ Guidance for selection of target cell

- The number of adjacent cells, cell packaging, and the distance between cells in proximity to the potential target cell shall be considered
- Installation of a trigger for the chosen target cell shall not impede the functionality of the original cell or RESS design and its' safety features
- Selection should follow a worst-case scenario in terms of thermal propagation
  - ➢ **Thermal couplings to other cells and to cooling mechanisms**
  - ➢ **The thermal insulation around cells**
  - ➢ **Geometrical aspect of electrical configuration, e.g. series or parallel connections**
  - ➢ **Venting paths inside the RESS**
  - ➢ **Configuration of battery management sensors and sampling rate**

Trigger method	Applicable cell type	Application at RESS Subsys-tem Level	Application at RESS Level	Application at Vehicle Level
Internal heater	cylindrical, pris-matic cells or pouch cell with adapted heater	Yes	Yes	Yes
localized rapid exter-nal heating	any cell type with limitations given in 6.7.7.1	Yes	Yes	Yes
Nail pene-tration	any cell type	Yes	Yes	No

Note: Additional guidance is available as remarks in the table.

Evidence of thermal runaway in triggered cell

- **Main criteria and supplementary criteria**
- **Main criteria based on energy density of the cell (Note: The main criteria are provisional, and may be subject to revision after the DIS ballot**

Cells with energy density less than 130 Wh/kg

Main criteria (for more than 3 s):

Temperature exceeding the normal operation temperature

Temperature rise dT/dt > 1 K/s

Cells with an energy density of 130 Wh/kg or more

Main criteria (for more than 0.5 s):

Temperature exceeding the normal operation temperature

Temperature rise dT/dt > 15 K/s

For both cell categories, one of the main criteria may be substituted by 2 or more supplementary criteria:

Test operando conditions:

Voltage drop

Fire

Venting gas or smoke

Occurrence of ejected solid material

BMS faults, e.g. insulation fault between cell monitoring controller And battery management controller, cell voltage invalid fault or "out of range"

Post-test disassembly observations:

Mass loss greater than the electrolyte mass of the initiated cell

RESS vent or cell vent activation

RESS or cell rupture

RESS or cell deformation

Material formation indicating high temperature, e.g. moten and re-solidified Al and/or Cu

Specific reaction products, e.g.Ni and/or Co metal, Li-Al oxide

Total or partial absence of current collector foil

Thermal decomposition of polymer materials, e.g. separator and/or isolation material

Test data and measurement recordings

- ❑ **Minimum set of data and information that shall be included in test report**
- ❑ **All data measurement systems shall be referenced to the same starting time**
  - For RESS or RESS subsystems
    - ➢ **Identification of test method, chosen trigger method and description of test setup used**
    - ➢ **Test conditions (e.g. ambient temperature, SOC, other pre-conditioning parameters)**
    - ➢ **Battery management system live-data, if available (e.g. single cell voltages, temperatures, isolation faults, other warnings) recorded at a rate that matches the systems' maximum output rate**
    - ➢ **Temperature of the target cell (°C) or temperature of vented gas from the target cell**
    - ➢ **Temperature of one adjacent cell (if possible)**
    - ➢ **Independent measurement of DUT voltage as a function of time and if possible, include the BMS pack voltage for comparison**
    - ➢ **Voltage of the target cell (if possible)**
    - ➢ **Video and audio recording including indication of a time stamp of any observable system state change during test (any flames, flares, smoke, explosions)**
    - ➢ **Condition of DUT at the end of test supported by photographs (before and after test) or video**
  - For Vehicle level test
    - ➢ **Same as above + warning indications or alarms to vehicle occupants**

Test events and outcome descriptions

- Establish common terminology of events and test outcomes to facilitate comparison

Events:

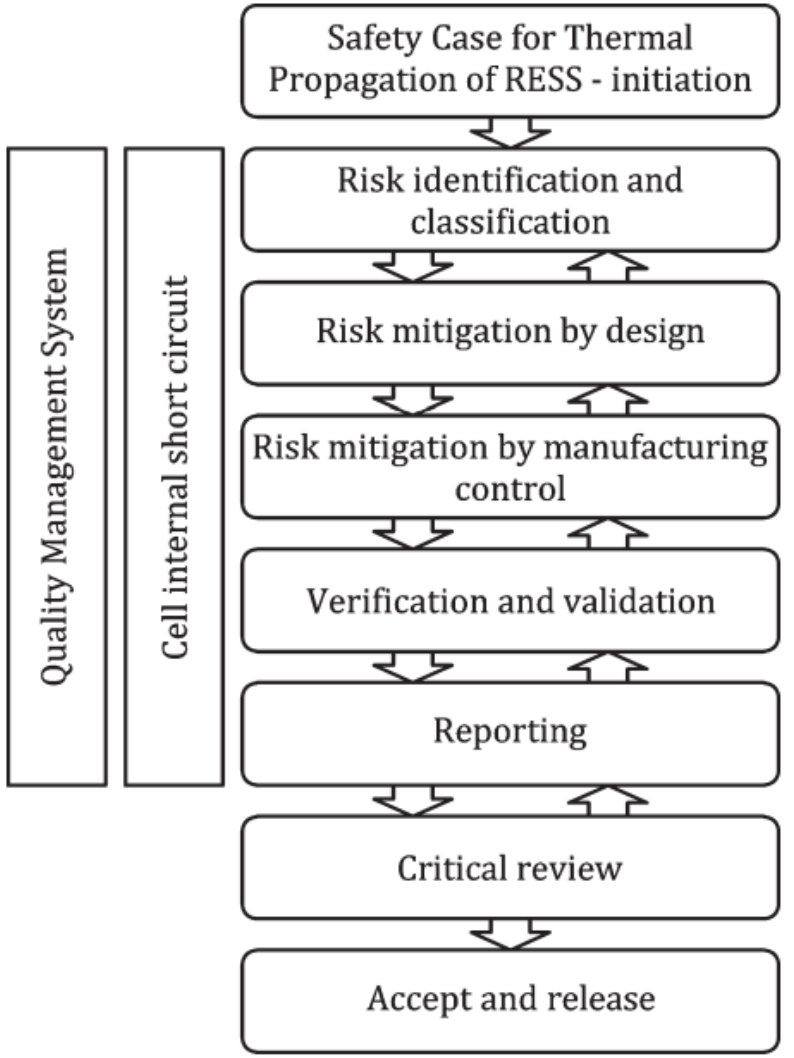
- Deformation
- Venting
- Leakage
- Smoking
- Rupture
- Fire
- Explosion

Test outcomes:

Scenario	Description	Effect
0	Target cell was not triggered to thermal runaway by the chosen trigger	No thermal event of target cell.
1	Target cell thermal runaway successfully initiated by chosen trigger method.	No thermal event of target cell. System controls and mitigations have stabilized the cell.
2	Target cell thermal runaway successfully initiated by chosen trigger method.	Target cell is destroyed by thermal runaway, but there is no propagation to adjacent cells.
3	Target cell thermal runaway successfully initiated by chosen trigger method. Propagation is observed.	Target cell is destroyed by thermal runaway. Propagation occurs in adjacent cells but does not spread beyond cell-bloc or module.
4	Target cell thermal runaway successfully initiated by chosen trigger method. Propagation is observed.	Target cell is destroyed by thermal runaway. Propagation occurs in adjacent cells, cell-blocs or modules but is arrested so that no full pack thermal event occurs.
5	Target cell thermal runaway successfully initiated by chosen trigger method. Propagation is observed.	Target cell is destroyed by thermal runaway. Propagation occurs in adjacent cells, cell-blocs or modules until full pack thermal event occurs.

Guideline for demonstration of thermal propagation risk mitigation

- **Objectives:**
  - to identify and evaluate the risk of thermal propagation within a RESS/RESS subsystem due to thermal runaway caused by internal short-circuit of a single cell
  - To demonstrate that appropriate and reasonable measures have been taken to eliminate hazards when possible and to mitigate harm for persons at risk
- **A systematic work process is applied, which comprises a defined sequence of steps that shall be performed and documented in a comprehensive and transparent manner to develop a safety case for thermal propagation of the RESS**
- **The safety case for thermal propagation of the RESS does not include faults in cell- and RESS electronics since these belong to the scope of ISO 26262**



Contents of safety case for thermal propagation of the RESS

❑ Description of the lithium-ion RESS

❑ Operational description of functional units

- functional operation of relevant systems and components and their inter-relationships shall be provided
- an explanation shall be included regarding which functions and unit processes are included in the thermal propagation safety demonstration

❑ Allocation procedure

- conditions that may result in internal short-circuit and thermal runaway of a single cell shall be identified and allocated to appropriate components or functional units within the system
- the associated preventive and/or mitigating functions and/or actions adopted by the RESS and/or vehicle to manage thermal propagation should also be identified

❑ Data sources and quality requirements

- the relevance and appropriateness of the data shall be described and justified
- Different types of data that can be used
- Major uncertainty factors
- Quality of data:

  precision – completeness – representativeness – consistency – reproducibility - sources

Contents of safety case for thermal propagation of the RESS

- ❑ **Assumptions**
- ❑ **Limitations of analysis**
- ❑ **Risk identification and classification**
  - to identify the hazard and determine the likelihood and severity of the occurrence
  - an appropriate recognized industry standard method or equivalent, shall be used to identify and evaluate risks and hazards levels to produce the risk assessment inventory
- ❑ **Risk mitigation by design**
- ❑ **Risk mitigation by manufacturing control**
- ❑ **Verification and validation of data**
  - Documentation of different test/verification methods methods and different types of data
  - Completeness check
  - Sensitivity check
  - Consistency check
- ❑ **Reporting**
- ❑ **Critical review**
- ❑ **Supportive templates (Annex C and D)**