Li-batteries hazards analysis

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Content

1. Identification of the Li batteries hazards
2. Source of the Li batteries hazard
3. Quantification of the hazards
4. Propagation issues
5. Calculation of the thermal protections
6. Risk assessment
1. Identification of the Li batteries hazards

Potential hazards of Lithium batteries

✓ The potential hazards of batteries
  o Electrical (for high current or high voltage applications)
  o Thermal runaway due to cumulative Electrical and Electrochemical hazard
  o Chemical (in case of electrolyte leakage)
  o Mechanical (in case of overpressure and burst, flying parts)

✓ The major possible consequences in case of thermal runaway:
  o Gas emission
    o According to composition potentially flammable/toxic/explosive
    o Volume with potential pressure increase in the surrounding environment
  o Flame and heat emission, with possible propagation to other cells or batteries, battery casing, packaging or other surrounding goods in the shipment.
  o Rapid disassembly, flying parts to the surrounding environment
  o Electrolyte or other raw materials leakage
2. Source of the Li batteries hazards

Thermal runaway: a chain of chemical reactions (example: case of Lithium ion LCO technology)
3. Quantification of the Li batteries hazards

Thermal run-away: reaction energy of Li-ion cells (results Saft & Ineris for LCO technology)

- Positive/electrolyte
- Negative/electrolyte
- Electrolyte
- Gas combustion

Total reaction energy per Kg

The gas combustion represents >50% of the total

Gazoline versus Li-ion:
Total combustion energy per kg

- Gazoline
- Li-ion

Li-ion runaway energy 20 times less than gasoline

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4.1 The root causes for propagation

- Ignition of one cell in a battery or in a box

- Thermal run-away propagation

- Heat transfer & flames, burning of flammable gas, burning of surrounding case or packaging can contribute to the propagation => All possible consequences are to be controlled

- Flames extinguishing may not be sufficient in case of « High density » packaging.

- In case of flame extinguishing systems, the gas flammability risk has to be taken in account.
4.3 The root causes for propagation: heat transfer

Thermal profile in case of 1 cell/battery run-away, high density packaged

- Local high temperature risk
- Thermal run-away propagation
- Average high temperature risk
- Cooling down
4.4.1 The benefit of thermal insulation

Thermal profile in case of 1 cell/battery run-away, low density package

Local high temperature risk mitigated by distance/thermal insulation

Cooling down

Temperature homogeneity improved during cooling

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4.4.2 The benefit of thermal insulation

Thermal profile in case of 1 cell run-away, low density package

Ignition of one cell in a battery or in a box

 Thermal insulation + flame extinguishing

 Cooling down

A single cell runaway may not be a critical event in transport and storage when the thermal runaway propagation is controlled
5.1 Calculation of the thermal protection

Comparison of a model and a thermal runaway heat propagation test, with various cushioning materials (sand, vermiculite, pyrobubbles, absorbant). Test made by Accurec and Simulation Model of RECHARGE.

**Test description:**
(ACCUREC)

**Insulation/cushioning material**

- d=15mm
- T5, T4, T3, T2, T6
- Drum
- Li-ion battery T1
- Heater

**Model description:**

- Cushioning material
- Heat source
- Heat transfer
5.2 Calculation of the thermal protection

The simulation is showing results close to the test results for the cell temperature and the different layers of the cushioning materials during the cooling phase.

Vermiculite

Sand
5.3 Packaging of battery waste: simple rules for cushioning calculation

- Weight and volume ratio in an homogeneous mix of batteries and cushioning material for an objective of 100°C outside

<table>
<thead>
<tr>
<th></th>
<th>vermiculite</th>
<th>sorbix</th>
<th>Pyrobub.</th>
<th>Absorbant</th>
<th>sand</th>
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</thead>
<tbody>
<tr>
<td><strong>weight ratio vs battery</strong></td>
<td>0,4</td>
<td>0,4</td>
<td>0,6</td>
<td>0,6</td>
<td>1</td>
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<tr>
<td><strong>volume ratio vs battery</strong></td>
<td>10</td>
<td>5,5</td>
<td>5</td>
<td>1,8</td>
<td>1,6</td>
</tr>
</tbody>
</table>

The model allow to define the correct packaging cushioning for any type of Li battery product and packaging.
6.1 Risk assessment principle

The risk is based on the probability of the hazard event and the level of severity of the effect in case the hazard occurs.

- The probability of the hazard event may be assessed based on
  - The status of the battery
    Example: scale for the Battery probability of internal thermal run-away versus its status for some battery status:
    Battery damaged & defective, without protection > battery in non-UN package (including short circuit risk) [10E-5??] > battery used in charge [10E-5 to 10E-8] > battery used in discharge > battery used at rest > battery new at rest in UN package [10E-9 to 10E-10]
  - The probability to observe a level of effect such as the one possible in case of maximum hazard abuse.
  - The hazard effect severity level has to be assessed per transport mode for each type of hazard.

Specific mitigation measures (包装 protections, etc.) are required when the risk is out of the acceptable level.
6.2 Risk assessment & mitigation measures

Risk is to be mitigated at an acceptable level when there is an unacceptable hazard effect severity with an unacceptable probability.

Different thresholds and or mitigation measures may be defined depending on the transport mode.
6.1 An example of risk mitigation measure: a suitable packaging for each case

- Comprehensive packaging should include protection against heat and flames propagation, disassembly and gas release effect.

![Diagram showing risk of runaway propagation and the impact of packaging density on temperature]

- **Low density packaging**: Lower temperature corresponding to low SOC or less reactive chemistries.
- **Comprehensive packaging**: Risk of runaway propagation from cell to cell or battery to battery.

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**Graphical Representation**

- **High density packaging**
  - Max temperature of the cell in runaway (°C)
  - Cells weight % of total package weight
  - No runaway propagation from cell to cell or battery to battery:
    - LOW DENSITY PACKAGING

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**Risk of runaway propagation**

- COMPREHENSIVE PACKAGING
Thank you for your kind attention!

The Advanced Rechargeable & Lithium Batteries Association

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