Claude Chanson

Li-batteries hazards classification

JRC Petten workshop, March 8th, 2018
1. Identification of Li batteries hazards
2. Li-ion batteries hazards background
3. Li-ion batteries hazards quantification
4. Tests data base
1. Identification of the Li batteries hazards

Potential hazards of Lithium batteries

✓ The potential hazards of batteries
  o The Chemical hazard
  o The Electrical hazard (and the case of high voltage)
  o Cumulative Electrical and Chemical hazards can lead to thermal run-away: heat, flame, mechanical hazards, and chemical hazards (gas properties, smoke)

✓ The three major possible consequences in case of thermal runaway:
  o Flammable/toxic gas emission (possibly bursting: mechanical hazards)
  o Flame ignition, and possible flame propagation in the cells or batteries casing and packaging.
  o Heat emission and Thermal Runaway Propagation from cell to cell or battery to battery, in absence of flames.
2. Source of the Li batteries hazards

Thermal run-away: a chain of chemical reactions
3. Quantification of the Li batteries hazards

**Thermal run-away: reaction energy of Li-ion cells**

**Total reaction energy per Kg**

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

**Gazoline versus Li-ion:**

**Total combustion energy per kg**

- The gas combustion represents >50% of the total.
- Li-ion runaway energy (5-20 times less than gasoline.)

The Advanced Rechargeable & Lithium Batteries Association
# 4. Tests database

Published and non-published data have been analyzed to fill an homogenous table of test results:

<table>
<thead>
<tr>
<th>Product description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary/sec.</td>
<td>Chemistry</td>
</tr>
<tr>
<td>P/R</td>
<td>Chemistry name</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abuse</th>
<th>Test type</th>
<th>Number of cells in test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test type</td>
<td>test spec</td>
<td>Number</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heat</th>
<th>Flame</th>
<th>Total reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Max Temperature</td>
<td>Reaction initial temperature</td>
<td>Energy of reaction (solids)</td>
</tr>
<tr>
<td>°C cell surface</td>
<td>*C Cells surface</td>
<td>kJ</td>
</tr>
<tr>
<td>gaz</td>
<td>Max Temperature</td>
<td>Volume at T</td>
</tr>
<tr>
<td>°C gaz</td>
<td>m³</td>
<td>moles</td>
</tr>
</tbody>
</table>
### 4. Tests database

Published and non-published data have been analyzed to fill an homogenous table of test results: 199 tests results collected.
4. Hazards quantification: tests categories

Two different categories of quantification test must be separated:

1- measurement of the total combustion reaction: these tests are based on a non-limited heat source (like permanent Infra Read heaters, or fire sources in a Tewarson calorimeter). The aim is to achieve the complete reaction of the battery materials. The results indicates that most Li-ion batteries have rather similar results and behave like combustible materials.

2- measurement of the thermal runaway reaction: these tests are based on a controlled abuse condition initiating the reaction. The aim is to measure the reaction consequences, including propagation ability. The results indicates that the the batteries have various results depending on their chemistry, design, state of charge, etc...
4.1 Total combustion of Li-ion batteries: total heat released

Specific case of total combustion: the total heat released has been measured in lab tests with complete combustion (fire of IR heating)
- The total heat is proportional to the cell size.
- The **4 to 10 MJ/kg maximum**
4.1 Total combustion of Li-ion batteries: total heat released

The maximum total heat of combustion of Li batteries is about 5 times less than organic materials like plastic or paper (10-40 MJ/kg)
4.1 Total combustion: HRR plastic/paper trash

The Heat Release Rate (HRR) is the measure of the fire power.
Example of 136 L (30 gal) trash containers made from H.D.polyethylene (HDPE) and loaded with cellulosic debris. (U.S. D.O.C., TEST FR 4018 April 24, 2003)
Each trash container was approximately 515 mm (20.25 in) in diameter and 700 mm (27.5 in) tall. The trash container alone had a mass of 3.6 kg (8 lbs). Each trash container had 10 kg (22 lbs) of debris “typical” of a construction site. The debris consisted of cut pieces of “2 X 4” lumber, sawdust, cardboard, paper, and cups, food wrappers and paper bags from a fast food restaurant (http://ws680.nist.gov/publication/get_pdf.cfm?pub_id=861237)

Figure 2. Graph of Heat Release Rate versus Time for Trash Containers 1 and 2.
The Heat Release Rate (HRR) has been measured in tests with various number of cells: single cells to large batteries. The max HRR per kg of batteries is decreasing with large batteries because not all the cells are reacting together. Therefore the cumulated maximum is not proportional to the size of the battery.
4.2 Thermal runaway quantification: Heat release

Thermal runaway heat of reaction* of all Li-ion chemistries, various type of abuse:
- sometimes limited (particularly for low SOC cells- see specific slides)
- Always **less than 7 kJ/Wh (or 1.0 MJ/Kg)**: compared to other combustibles, about 20-40 times less energy than plastic, fuel, and other combustible materials.

*Calculated based on the maximum temperature of cells/batteries and specific heat
4.2 Thermal runaway quantification: gaz

Gaz volume emitted (without combustion) during thermal runaway of all Li-ion chemistries, various type of abuse:
- Maximum gaz volume is roughly proportional to the cell size - But the reaction is sometimes limited, as in the case of heat produced (low SOC).
Thank you for your kind attention!

The Advanced Rechargeable & Lithium Batteries Association
www.rechargebatteries.org
Avenue de Tervueren, 168 - Box 3
B - 1150 Brussels, Belgium
Tel. +32 2 777 05 67
Fax +32 2 777 05 65