Managing Fire Risk from Lithium-ion Batteries

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Fire Sector Summit
Managing Fire Risk from Lithium-ion Batteries

Think Globally – Act Locally
Represented across the world in 20 countries with 22 sites

Founded 1986 by Helmut Dennig
Head Office in Bad Oeynhausen, Northern Germany
Production and sales operations in countries

2017
Turnover: €158 Million
Number of employees: 750

Production + Sales
1986 Germany
1991 USA
1993 Italy
1993 France
1998 Czech Republic
2000 Great Britain
2016 China

Sales
1994 Netherlands
1998 Austria
2000 Belgium
2001 Sweden
2004 Switzerland
2005 Spain
2007 Denmark
2008 Poland
2011 Slovakia
2014 Finland
2016 Mexico
2016 Portugal
2017 Canada

Dealers
Ireland
Norway
Hungary
Romania
The development of electric energy accumulators rised during the last years more and more. Today the most important accumulator is the Lithium-ion battery. This kind of Batterie is divided into three classes:

<table>
<thead>
<tr>
<th>Low capacity</th>
<th>Medium capacity</th>
<th>High capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=100 Wh per battery</td>
<td>&gt;100 Wh and &lt;= 12 kg brutto per battery</td>
<td>&gt;100 Wh and/or &gt;= 12 kg brutto per battery</td>
</tr>
<tr>
<td>Computer, Multimedia, Small tools, Small electric</td>
<td>Pedelec, E-Scooter, Light-Electric vehicles, Cell for high capacity battery</td>
<td>Combination of medium size cells</td>
</tr>
</tbody>
</table>

I guess that the main items are well known and it is not necessary to describe the battery itself.
Lithium-ion Batteries Basics

To get an idea of the embedded energy, the energy content of different units is shown in the following table:

<table>
<thead>
<tr>
<th>Part</th>
<th>Electric Energy</th>
<th>Total Energy</th>
<th>Total Gas</th>
<th>Peak Gas</th>
<th>Enough Energy to melt iron</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wh</td>
<td>Wh</td>
<td>kj</td>
<td>l</td>
<td>kg</td>
</tr>
<tr>
<td>Cell 2.2 Ah</td>
<td>8.70</td>
<td>100</td>
<td>360</td>
<td>11</td>
<td>44</td>
</tr>
<tr>
<td>Powertool - pack made of 20 cell 2.2 Ah</td>
<td>174</td>
<td>1.740</td>
<td>6.264</td>
<td>220</td>
<td>44</td>
</tr>
<tr>
<td>Coffe bag cell 40 Ah</td>
<td>160</td>
<td>1.600</td>
<td>5.760</td>
<td>200</td>
<td>6.00</td>
</tr>
<tr>
<td>Hybrid-battery 1 kWh</td>
<td>1.000</td>
<td>10.000</td>
<td>36.000</td>
<td>1.250</td>
<td>150</td>
</tr>
<tr>
<td>Car battery 20 kWh</td>
<td>20.000</td>
<td>200.000</td>
<td>200.000</td>
<td>12.500</td>
<td>300</td>
</tr>
</tbody>
</table>
Lithium-ion Batteries Basics

To withstand this energy, the Cabinets are built from panels made of steel sheet covered Rockwool. The solution is tested for 120 minutes at about 1100 °C.

Pictures show the parts during and after test.
DENIOS AG developed fire rated storage systems for the storage of hazardous and flammable chemicals. This system is used in different industries, also in the automotive industry. Based on this experience, DENIOS AG was asked if this system is also suitable for storage of Lithium-ion batteries.

Due to the fact that there were and are no legal regulations or requirements to respect for this type of battery, the risk assessments and chosen storage solutions of our customers and industry users were based solely on theoretical considerations.

DENIOS AG started workshops with different customers, certification institutes, fire consultants, fire brigades and subcontractors to find out realistic solutions.

It became clear that companies are generally reluctant to talk about their experiences with the Lithium-ion batteries and this makes the formation of an industry consensus challenging.
Based on request of different clients DENIOS AG made an analysis of risk generated by Lithium-ion batteries. Following risk were detected:

- When a Lithium-ion cell reaches high temperatures or is subjected to over-charging, the structure of metal oxides is destroyed. This damage is highly exothermic, resulting in high energy release, producing oxygen and the electrolyte fluid boils. This produces highly flammable gas. If the temperature increases to the flash point, thermal runaway starts.

- The extinguishing of this fire is difficult, because the Lithium-ion cells produce the oxygen by themselves.

- When combined with water, the Lithium produces an aggressive acid, hazardous to the environment.

- The dissolving Lithium-ion cells produce a mixture gases, such as carbon monoxide, methan, hydrofluoric acid, hydrogen, nitrogen oxide, oxygen, hydrocarbonates as Ethene, Ethine, Benzole.
Lithium-Ion Batteries

During the dissolving of Lithium-ion batteries a flammable gas is produced with potentially explosive effect. After ignition there is a huge increase in volume.

Each cell burst on ignition, which ignites the neighbouring cell, this is called thermal runaway. The process is like a chain reaction and increases in speed. After the bursting of all cells, the remaining material is burning with high temperatures.

When considering the storage of Lithium-ion batteries, the following therefore needs to be considered:

- To allow pressure relief inside and to avoid the forced opening of doors, an explosion relief hatch was designed.
- The relief hatch opens during the explosive chain reaction, with a pressure much lower than the pressure required to force open the doors.
- After explosion the hatch is closed again and withstands the fire inside for up to 120 minutes.
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Lithium-Ion Batteries storage solutions

In the following slides, I would like to present some of the technical solutions adopted from experience for safe storage of Lithium-Ion Batteries.
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Pressure relief hatch

- 120 minutes fire resistant trap
- Opens at 600 Pa and close after explosion
- Tested by notified body
- Heat insulated

Gas detector

- CO programmed gas detector
- Installed to detect smoke before temperature rises significantly
- Supply signal to close doors and ventilation fire traps automatically
- Shut down ventilation fan and electrical installation
- Routing signal to general office
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Water sprinkler
- Dry riser water sprinkler system
- Target to cool down the burning cell
- Cooled cells do not ignite the neighbouring cell

Water extraction system
- Drain valve for water extraction from sump
- Installed to extract contaminated water directly into safe storage tank
- No contamination of environment
- Extraction without door opening
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Heat and smoke alarm system
- Combined heat and smoke sensor
- Routing alarm to general office
- Sends signal to doors and shut down ventilation system
- Shuts down charging or test cycle

Technical ventilation
- Permanent operating ventilation against concentration of hazardous gas
- Air flow is closed automatically by heat or signal
- Air flow trap is certified up to EI 120
- Air flow monitoring system with alarm possible
Managing Fire Risk from Lithium-ion Batteries

Cable and pipe penetration
- Fire rated system for cable and pipe penetrations
- Gas, explosion and watertight
- Possibility to replating
- System possible for different diameter

CO₂ fire extinguisher system
- Automatic fire fighting system
- No water contamination
- Permanent system
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Spill sump
- Fluid leakproof spill sump made of painted or hot dip galvanized steel
- Situated as base of cabinet or container to avoid environment contamination
- Tested according to EN ISO 3452-1

PE spill sump
- Additional spill sump for aggressive fluids
- Placed inside the steel sump
- Conductive version possible
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Combinated heat- and cooling system (A/C)
- CFC free heating and cooling system
- Split arrangement of compressor and heat exchanger
- Temperature range can be determined upon request
- Additional electric heater for humidity control

Magnetic door restraints
- Comfortable door cladding and closing system
- Door closes automatically after detection of fire
Today we divide the different solutions roughly into following solutions:

- Storage of charged, new batteries for production of new cars and spare parts inside of a storage container.
- Technical safety room for internal climatic bench. Provision to protect the area outside of cabinet in case of fire. Walk in version.
- Technical safety room able to create climatic conditions for tests of batteries. Walk in version with fire rating.
- Garage for undamaged cars for safe charging of batteries.
- Store for crashed vehicles with unknown condition of batteries.
- Store for batteries with unknown conditions (damaged, empty, partly charged)
• Generally all cabinets are fire rated with REI 90 resp REI 120 according to EN 13501-2 including the wing doors for fire load from inside and outside.
• Fire rating is tested in fire tests and confirmed by international notified body
• The ATEX rating upon request, mostly Ex zone 2.
• All cabinets and containers are equipped with spill sump.
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Technical Safety Room: Lithium-ion Test Cabinet

- 90 minutes fire rated cabinet
- 90 minutes fire rated doors
- Fire rated explosion relief hatch
- Reinforced floor for climatic bench
- Smoke and heat sensors for on site fire alarm system

- Internal cable tray
- Modular and fire rated cable and pipe feed trough
- Explosion relief hatch with snow roof
- Dry riser water sprinkler system
- Connection for sump water extraction.
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Technical Safety Room: Lithium-ion Clima Test Cabinet

- 90 minutes fire rated cabinet
- Test cabinet with clima control for -40 up to +60 °C.
- Explosion relief with duct to deviate smoke gas outside the building
- Restricted height
- 240 mm mineral fiber board insulation to avoid condensation outside
- Thermal divided cable feed through
- Extraction fan
- Dry riser system for cooling
- Alarm system for shut down and information
- Build in compressor system for heating and cooling
- CO gas detector for early smoke detection
- Fire rated doors with thermal barrier
- Heated door frame to avoid freezing
- Inclined sump for controlled condensation and cooling water evacuation with drain valve
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Lithium-ion Batterie Storage Container

- Container system inside Ex II 3 G Eex e II T3
- 90 minutes fire rated storage container
- 90 minutes fire rated doors
- Automatic door cladding and closing system
- PE sump inliners
- Gas alarm device
- Combined cooling and heating system
- 2 x explosion hatch
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Technical Safety Room: Lithium-ion Car Storage Container

- 90 minutes fire rated container
- CO₂ fire extinguisher system
- Gas cylinder store separated
- Spill sump 3 x 800 l
- Lights inside

- Smoke and heat sensors for on site fire alarm system
- Pressure relief valve
- Automatic door restraint and closing system
- Technical ventilation system
- Combined heating- and cooling system
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Technical Safety Room: Lithium-ion Crashed Car Storage Container

- Container system inside Ex II 2 G Ex e II T3
- 90 minutes fire rated container
- Insulated Ex classified roller shutter
- 30 minutes fire rated doors
- Spill sump 2400 l
- Lights inside
- Gas alarm device

- Air circulation heating system
- Explosion relief
- Automatic door restrained and closing system
- Spill sump 2400 l
- 2 x Technical ventilation
- 2 x Technical ventilation
- Air flow monitoring
Thank you for your attention.

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