The Future of Battery Technologies – Part IV
Testing & Evaluating Lithium Batteries
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In order to ensure that a battery-driven product functions in a good way, there are different methods of testing and evaluating the battery’s functioning and safety. There are four different categories of tests that can be used in order to qualify a battery:

- **Electrical performance testing** – different types of test that investigate the battery’s electrical functioning, for example available capacity at different loads and surrounding temperatures, cycle lifetime, calendar lifetime in storage, charging receptivity, impedance as a function of charging state etc.
- **Safety testing in relation to environmental effects** – various tests that simulate different kinds of environmental conditions to which the battery could be exposed, for example, vibrations, falls, knocks and blows, damp, high temperatures or quick temperature changes.
- **Safety testing in relation to faults or incorrect usage** – various tests that evaluate the battery’s ability to deal with different types of stress that can arise intentionally or unintentionally when using the product, for example, overcharging, short circuiting, incorrect installation and similar situations.
- **Effect on the environment** – chemical analysis of heavy metal content.

Some of these tests have to be carried out because of rules and legal requirements. Amongst these is transport testing in accordance with the UN’s transport rules for dangerous goods (UN Manual of Tests and Criteria section 38.3) which is required in order to transport lithium batteries and cells and products that contain lithium batteries, irrespective of the type of transport. Several countries apply limits for certain heavy metals in batteries. The chemical elements that are most commonly regulated are mercury, cadmium and lead. For example, the EU Battery Directive regulates all three of these elements and specifies prohibitive as well as marking requiring heavy metal content.
Electrical Performance Testing

A battery’s technical specifications say a lot, but not everything, that an instrument manufacturer needs to know about the battery cell or battery pack that has been chosen to power a certain apparatus. Available battery capacity and the number of discharge cycles are two factors that are strongly affected by actual conditions of use. Similar battery cells from different manufacturers and even different models from the same manufacturer do not need to have the same properties, since the functioning of the battery is governed by those chemical reactions that are possible in each individual case. The balance between different components, additives, pollutant contents etc. are very important to cell chemistry. Cell design and the manufacturers’ recipes for electrode and electrolyte composition are carefully guarded secrets and are important competitive tools among manufacturers. The extent of the testing which is carried out by cell and battery manufacturers can also vary from case to case. Testing represents a cost, and one can therefore assume that low-budget products in many cases have undergone less extensive testing than advanced products from more renowned and experienced manufacturers.

Minimum Requirements in Standards

The type tests that are found in IEC standards are basic tools for evaluating lithium cells and batteries’ electrical properties. IEC 60086-1 and IEC 60086-2 lay down dimensional requirements for different cell types and sizes of primary batteries. The corresponding standard for rechargeable cells and batteries is IEC 61960. It is generally the case that standard requirements are minimum requirements that all batteries must comply with. Most modern, battery-driven products available on the market impose higher or more extensive requirements on their batteries and so standard tests should be supplemented with application-specific discharge and lifetime tests.

When buying cells and batteries, one should demand that they fulfil the relevant standard requirements. Cell and battery suppliers should be able to provide reports from tests carried out and be able to account for the extent and frequency of tests, both as part of ongoing production checks and those that are carried out in final checks on the finished cells and batteries. It is not unusual for low-budget cell and battery specifications to state that the product is designed to conform to the requirements of IEC standards without any such testing having been carried out, or that limited testing is carried out covering only parts of the standards. In some cases testing has been performed in connection with the original product launch but is not updated in connection with product development or changes in components.
Safety Testing for External Influences

The UN’s transport testing is a typical example of safety testing designed to establish the battery’s safety properties in the event of external influences. The test programme includes a total of eight tests designed to simulate conditions that could occur in a transport situation.

- T1 Simulation of high height (test to recreate low pressure when flying)
- T2 Thermal shock (exposing the battery to alternating high and low temperatures)
- T3 Vibration test
- T4 Fall impact test
- T5 External short-circuiting
- T6 Blow test
- T7 Overcharging test
- T8 Forced discharging

It is important to note that it is not enough to test the individual cells that are included in a battery pack and that the whole battery pack must be tested if it consists of several cells. Re-testing is also required if the product is modified in a way that could affect the results of testing and if the product’s weight (primary lithium batteries) or Wh-content or voltage (rechargeable lithium cells and batteries) are changed. As well as special testing, transport rules require that lithium batteries and products that contain lithium batteries are packed, marked and accompanied by safety documentation in accordance with given requirements. Some countries/transport authorities set higher requirements than those that normally apply in UN 38.3. Today, transports in the USA are subject to more extensive requirements.

UL and IEC standards consist of a combination of environmental influence tests and tests that simulate predictable types of incorrect use. The tests focus on evaluating fire-safety and the requirement for approval is generally that the cell or battery does not explode or burn during the course of a test. The tests included in UL or IEC are similar, even though there can be differences in the degree of strictness between the different standards. UL holds a strong position in North America whilst IEC dominates in the rest of the world.

When buying cells or batteries, you should insist that the cell or battery supplier has carried out tests in accordance with the UN’s transport requirements. If these have not been carried out, this can affect the timetable for the product launch and involve considerable costs for the equipment manufacturer, who must then take responsibility for carrying out the tests. Cell and battery suppliers should also be able to provide test reports from completed testing in accordance with UL 1642 (cells) and 2054 (battery packs) or IEC 60086-4 (primary lithium cells and batteries) or IEC 62133 (rechargeable cells and batteries) and to account for the extent and frequency of tests carried out, both as part of ongoing production checks and as final
checks on the finished cells and batteries. If, as a buyer, you are unsure whether the battery has been tested or whether the testing has been carried out in the right way, then you should carry out your own verification in accordance with relevant standard methods.

Regulated Heavy Metals are Uncommon

There is no named method that has to be used for chemical analysis of batteries. None of the listed substances; mercury, cadmium or lead contributes to the electro-chemistry in lithium batteries. There is therefore no reason for manufacturers to add them intentionally. To the extent that they do occur, it’s in the form of raw material contamination. It is extremely unusual for lithium-based cells and batteries to contain problematically high levels of these substances.

Battery Testing Standards

Below is a list of the testing standards mentioned earlier. Most national and regional standards, such as SS and EN, are based on the corresponding IEC standard and this is therefore referred to in the current version of IEC. In some cases, national standards are not updated at the same time as IEC and for that reason it is important to be certain that testing has been carried out in accordance with the current guidelines and, where necessary, supplement the tests carried out with further tests.

For transport rules, the method of transport governs which guidelines that apply, i.e. ADR/RID for land transport, the IMDG-code for sea transport and the ICAO-TI and IATA-DGR for air transport. These are updated regularly, but there is sometimes a time delay which leads to transport law guidelines referring to an earlier edition of the UN Manual of Test and Criteria.

**UN's transport testing for all batteries that contain lithium:** ST/SG/AC.10/11/Rev.5; UN Manual of Tests and Criteria, Rev.5 (2009)

**Primary batteries:**

- IEC 60086-1: Primary batteries - Part 1: General, Ed 10.0 (2006)
- IEC 60086-2: Primary batteries - Part 2: Physical and electrical specifications, Ed. 11.0 (2006)
- IEC 60086-4: Primary batteries - Part 4: Safety of lithium batteries, Ed. 3.0 (2007)
Rechargeable batteries:

- IEC 62133: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications, Ed. 1.0 (2002)
- IEC 61960: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications, Ed.1.0, (2003)

Note that several of the above standards are currently in revision.

Construction Requirements for Battery Powered Equipment

When applying for product certification for medical-technical equipment, an approved result of the safety test in accordance with IEC or UL standards constitutes a basis for being able to approve the battery as a safe component. This means that if there are several suppliers of cells and/or batteries for a specific item of equipment, then they must be approved individually in order to be used in the equipment.

CB-certification of products containing rechargeable Li-ion batteries requires testing according to IEC 62133 as of May 1, 2012, and that Li cells and batteries certified to UL 1642 and UL 2054, respectively, has to undergo and fulfil additional testing starting from May 1, 2011. Primary lithium batteries must be certified in accordance with IEC 60086-4. The corresponding timetable for products falling under IEC 60065 and IEC 60950-1 remains to be determined.

Product certification requires that the equipment must be safe if a component fails. Fire or dangerous explosions must not occur and a risk analysis is performed based on the test results of the device. For a primary battery or cell of the lithium type, protection is only required against reverse current. It may also be appropriate to specify regular checks on the protective components. For batteries or cells that are tested and certified as short-circuit-proof, no further protection is needed. For other batteries a current-limiting component is also required to limit the discharge current. The reverse and discharge currents that the battery is certified for must not be exceeded in the case of a fault.

For secondary lithium batteries, i.e. rechargeable batteries and cells, the charging battery protection circuits are investigated. The battery must be protected against excessive discharge current, charging current and charging voltage. Where appropriate, it may also be necessary to monitor the battery’s temperature in order to shut down the device and mitigate the effects in
case of over-temperature. If the battery protection is not certified, two independent protective measures are required for each of the three parameters, which is the most commonly occurring scenario.

In addition, a risk analysis based on testing should be carried out to show that it is improbable that faults should occur in both protective circuits simultaneously.