When lithium-ion batteries „escalate“

Researchers investigate how enclosures can protect against the consequences of a thermal runaway

Due to the growing number of lithium-ion batteries with a wide variety of cell chemistries, accidents will become more frequent. These are often associated with a self-accelerating rise in temperature, the thermal runaway. The thermal runaway describes exothermic reactions between different components of the battery, accompanied by an increase in temperature and pressure, the emission of various toxic, flammable and corrosive gases and the ejection of hot particles and sparks. In the research project “LIdEX”, the impact of such a thermal runaway on a surrounding enclosure was investigated in more detail.

The demand for applications of lithium-ion batteries (LIB) in hazardous areas is increasing. Such areas are characterized by the possible presence of an explosive atmosphere and occur, for example, in mines or the chemical industry. If a thermal runaway takes place in such an environment, the battery can act as an ignition source for the surrounding atmosphere (see Figure 1), which leads to a massive increase in the damage caused.

Figure 1

To protect the environment from the consequences of a thermal runaway, types of protection in accordance with the standard IEC 60079-0 can be used. One such type of protection is the so-called “flameproof enclosure” in which the battery can be enclosed. Due to their design, flameproof enclosures can withstand high mechanical and thermal loads. The aim of the WIPANO[1]-project “LIdEX” (lithium-ion accumulators in flameproof enclosures) carried out at the Physikalisch-Technische Bundesanstalt (PTB) was to characterize the dependence of the material load on the parameters cell chemistry, cell capacity, enclosure geometry and gas atmosphere inside the enclosure. The results are expected to provide guidance for standardizing the use of lithium-ion batteries in flameproof enclosures.

By varying the cell chemistry, it was possible to reproducibly determine the highest material load when using the electrode material lithium nickel manganese cobalt oxide in a ratio of 8:1:1 (NMC-811). Based on these tests, the volume and inner surface of the flameproof enclosure were varied. In contrast to the previous state of research, which only describes the relationship of the material load on the enclosure volume, it could be shown that it is additionally dependent on the inner surface.

[1] Knowledge and technology transfer through patents and standards

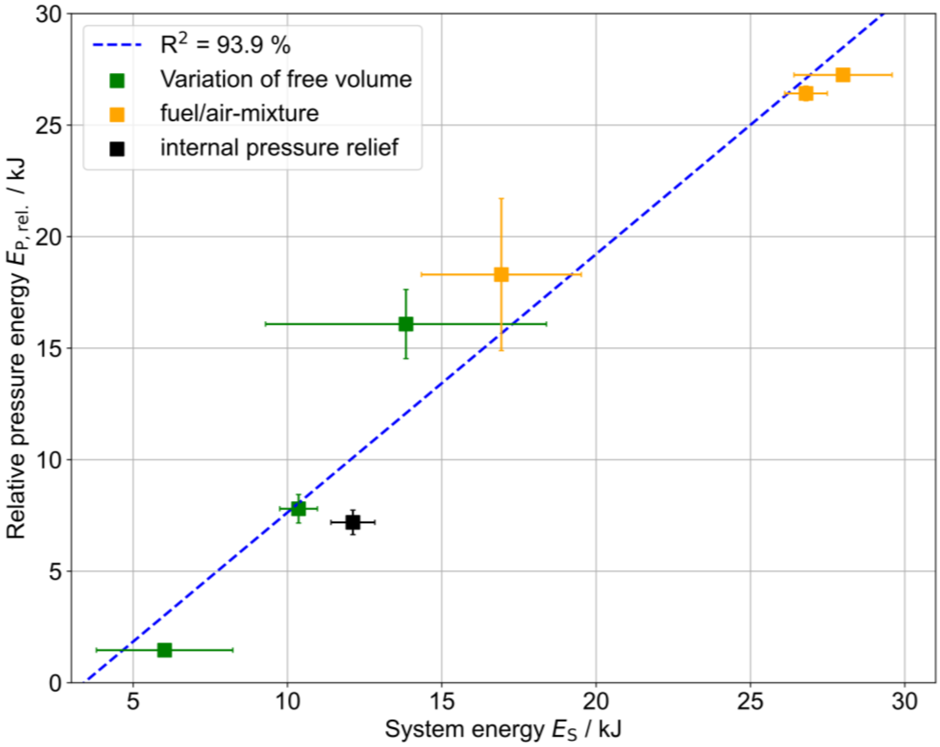

Figure 2

This behavior could be attributed to heat transfer phenomena. The energy of the system, consisting of the gas volume inside the enclosure itself and the lithium-ion battery, and its energy loss to the periphery are therefore decisive for the observed material load. This relationship can be illustrated using the relative pressure energy $E_{P,rel.}$ representing the material load and the system energy E_S, where a linear dependence was observed (see Figure 2). This correlation is independent of how the energy was introduced into the system, as the provision of an additional explosive atmosphere also obeys this dependence.

Furthermore, the reproduction of the thermal runaway caused by gas explosions was successfully carried out as part of this project. This aspect is particularly relevant for the conformity assessment of flameproof enclosures in accordance with the ATEX directive or the IECEx Scheme, as this would make it possible to avoid tests involving runaway batteries in the future.

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Figures:

Top and side view of a thermal runaway of a lithium-ion battery in a flameproof enclosure. Figure: Freyja Galina Daragan
Dependence of the relative pressure energy $E_{P,rel.}$ on the energy input into the system E_S. Figure: Freyja Galina Daragan

Contact:

Dr.-Ing. Stefan Essmann
Physikalisch-Technische Bundesanstalt (PTB)
Bundesallee 100
38116 Braunschweig
Tel.: 0531 592-3550
E-Mail: stefan.essmann@ptb.de
www.ptb.de/cms/de/ptb/fachabteilungen/abt3/fb-35/ag-355.html