Abstract Report

DÜPERTHAL®

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ICT

Study on the Effect of a Propagation Inside a Safety Storage Cabinet

1 Test Object and Experimental Setup

Test object for the propagation test was a DÜPERTHAL BATTERY line standard XL safety storage cabinet with the dimensions 2045 mm x 1194 mm x 612 mm (H x W x D) and a division of the storage capacity into four thermally separated compartments.
To measure and collect the flue gases of the propagating batteries escaping through the door gaps, the safety storage cabinet was installed in an enclosure with an inner volume of 2.18 m³. For this purpose, most of the free interior volume of the enclosure was in front of the cabinet doors. The exhaust air pipe of the passive exhaust duct was led directly out of the enclosure and sealed to the interior. Thus, the flue gases escaping through the exhaust air opening from the cabinet were directly led to the outside.

Inside the safety storage cabinet two prismatic lithium-ion battery cells (54 Ah, fully charged (SOC = 100 %)) of the current automotive generation were positioned on storage level 2. The battery cells were positioned directly next to each other, so they have passed one after each other in thermal runaway. For this purpose, an internal short circuit was induced in the first cell by a nail penetration test. Due to the heat transfer between the cells a thermal runaway was also initiated in the neighboring cell (cell propagation).

Two additional battery cells were (54 Ah, fully charged (SOC = 100 %)) were positioned above (storage level 1) and at some distance next to the two triggered cells (storage level 2).

The burst openings of the triggered cells pointed to the battery cell on the storage shelf above and to the battery cell on the right side of the same storage shelf to make further cell propagation more likely and to maximize thermal stress on the door mechanism.

The internal temperatures of the safety cabinet were monitored using the sensors shown in Figure 1.

Besides the temperatures in the cabinet, the flue gases escaping from the door gaps were also comprehensively analyzed using online FT-IR, liquid absorber with subsequent IC analysis of the anions, and GC and GC-MS methods.

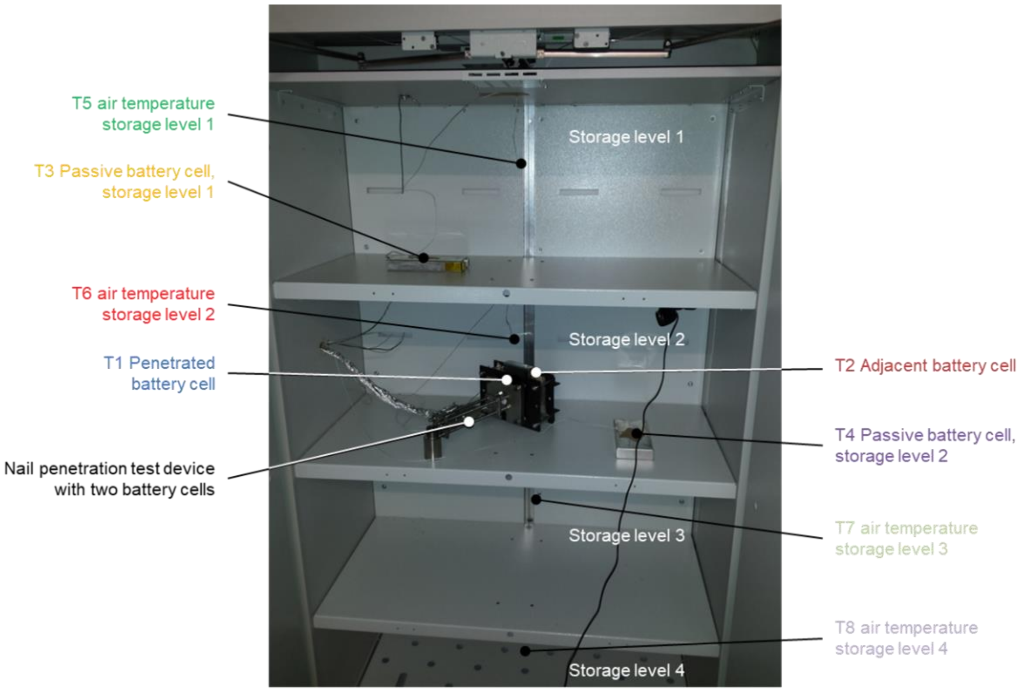


Fig. 1: Positioning of the four lithium-ion battery cells and the thermocouples in the safety storage cabinet

2 Temperature Profiles

Figure 2 shows the temperature profiles T1 – T8 of the different measurement points during the test. Approximately 1.8 minutes after starting the measurement an internal short circuit was triggered by the entry of the nail into the first battery cell. This caused a punctual increase of the temperature inside the battery cell to approx. 350 °C and the bursting of the burst disc of the battery cell. As a result, the cell contents were ejected very quickly and in a targeted manner. This explains the moderate temperature rise of the cell housing to approx. 350 °C and the higher temperatures of the particle beam of approx. 600 °C.

Due to the large-scale heating of the cell core of the second cell, a faster and more intensive conversion of the cell materials occurred (cf. Fig. 2 T2). The resulting explosive pressure shock was absorbed by the cabinet door's backdraft locking system.

Although, the surface temperature of the third cell located on the same storage level 2 temporarily rose to approx. 180 °C, the temperature was not high enough to thermally stress the cell inside enough to cause a thermal runaway. The temperature of the fourth cell, which was located on the top storage level 1, increased only slightly due to the separation by the thermally insulated storage shelf. This clearly shows the positive influence of spatial separation of the cells or thermal separation of the storage areas – as used in DÜPERTHAL BATTERY line safety storage cabinets – when storing Li-ion cells.

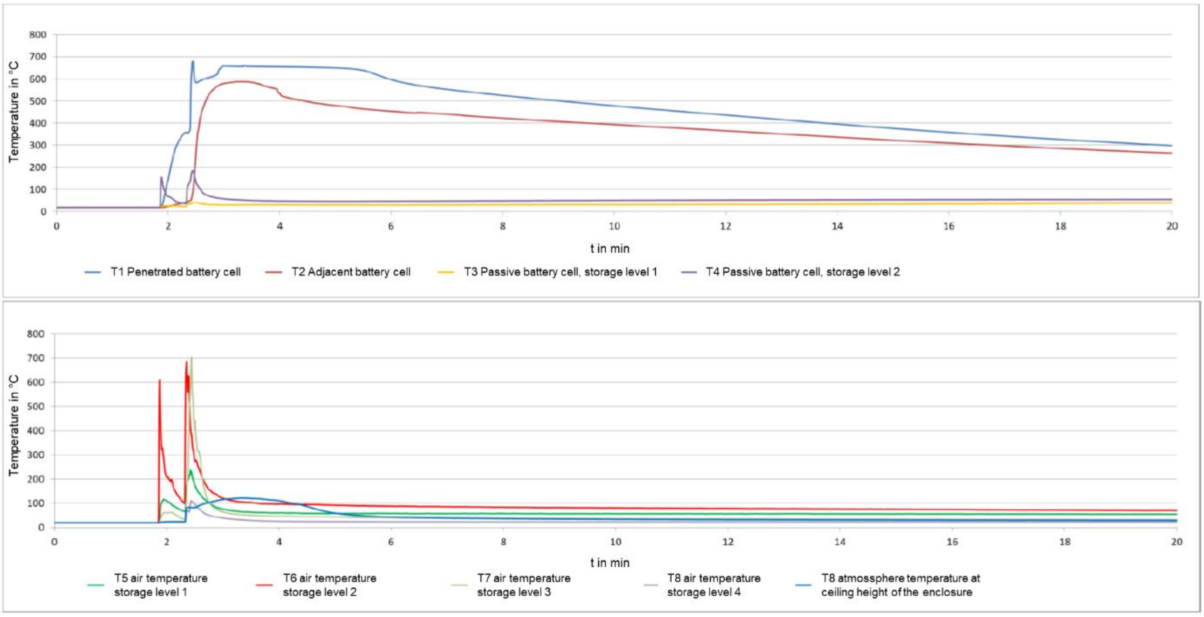
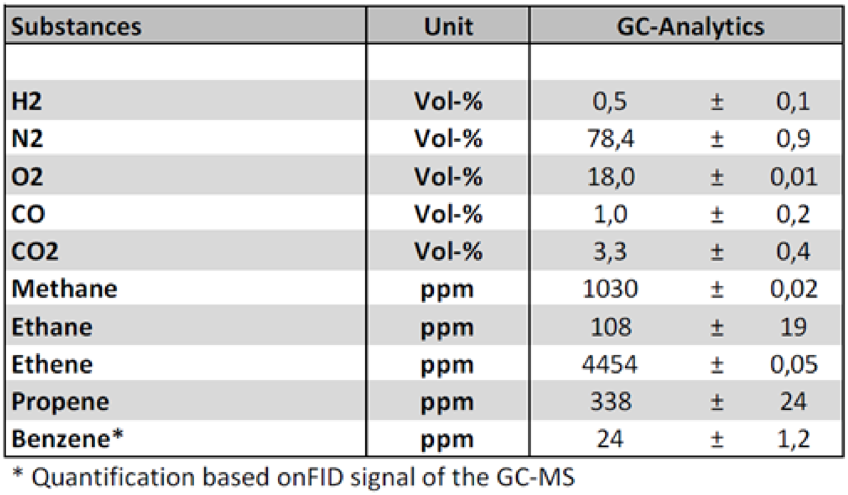


Fig. 2: Top: Profile of the surface temperatures of the four 54 Ah cells positioned in the safety cabinet.
Bottom: Temperature profile in the storage compartments and the outer enclosure

3 Gas Analytics

During the test, various analytical methods were used to analyze the flue gases escaping from the door gaps of the safety cabinet. Quantitative gas analysis revealed the following gas concentrations in the enclosure around the safety storage cabinet (see Table 1).

Tab. 1: Quantitative gas analytics of the main components via GC



Substances	Unit	GC-Analytics		
H2	Vol-%	0,5	±	0,1
N2	Vol-%	78,4	±	0,9
O2	Vol-%	18,0	±	0,01
CO	Vol-%	1,0	±	0,2
CO2	Vol-%	3,3	±	0,4
Methane	ppm	1030	±	0,02
Ethane	ppm	108	±	19
Ethene	ppm	4454	±	0,05
Propene	ppm	338	±	24
Benzene*	ppm	24	±	1,2

* Quantification based onFID signal of the GC-MS

The FT-IR method used allowed the observation of the time course of concentration of important main components in the gas phase. For the safety-critical assessment, the maximum values of the FT-IR method or the point concentration determinations of the other analytical methods after the thermal runaway were used.

In the evaluation, the maximum value of approx. 11,000 ppm (= 1.1 vol%) of carbon monoxide determined by FT-IR stands out. This value was confirmed by the single point measurement of the GC analysis (cf. Tab. 1). Thus, the acute exposure guide levels (AEGL-3 10 min: life-threatening hazard at 10 minutes exposure time)[1] of 1,700 ppm was far exceeded. Since in most cases the safety storage cabinet is installed in a larger (>> 2.18 m^3 free gas volume) and better ventilated room, and the exposure time in an emergency will be shorter, the expected exposure risk is significantly lower in most cases.

The determined gas concentrations can be converted to a larger room volume (v) as follows.

Det. gas conc. (ppm) x (2.18 m^3 / v m^3) = gas conc. in room volume v (ppm)

Thus, the AEGL-3 10 min. value would no longer be exceeded for a room larger than 14.2 m^3.

The calculation did not consider additional ventilation or fresh air supply to the room, which would further reduce the effective gas concentration.

In addition to the gas concentrations shown in Table 1, concentrations of acidic gases were also determined by liquid absorption followed by IC analysis. These measurements showed that the concentrations for hydrogen fluoride (HF) at 11.4 ppm and for hydrogen chloride (HCl) at 0.4 ppm were in each case even well below the AEGL-2 10 min. values (AEGL-2 10 min: serious, long-lasting, or escape-impeding effect at 10 min. exposure time)[1] of HF = 95 ppm and HCl = 100 ppm, respectively.

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[1] (https://www.umweltbundesamt.de/themen/wirtschaft-konsum/anlagensicherheit /aegl-stoerfallbeurteilungswerte; Access: 07.04.2019)

4 Summary

The test showed that the backdraft locking system of the safety cabinet can withstand the explosive pressure shock of an automotive cell with a capacity of 54 Ah and that the doors remain permanently closed and locked.

Furthermore, it could be shown that a spatial separation of the cells during storage and a thermal separation of the individual storage areas can effectively prevent the thermal runaway of further cells.

With the aid of gas analysis, it was possible to qualitatively and quantitatively determine the smoke gases that escape through the door gaps of the safety storage cabinet in the event of a fire. It was shown that the greatest hazard potential comes from escaping carbon monoxide. This potential hazard can be minimized by a well-ventilated installation site.

5 References

This abstract report summarizes the results of the test, which was conducted at the Fraunhofer Institute for Chemical Technology (ICT) in Pfinztal on September 11, 2019. The following results report serves as a basis:

Abert, M., Fanz, P., Frohberg, J. (28.09.2019): *Untersuchung der Auswirkung einer Propagation innerhalb eines Sicherheitsschranks mit Analytik*. Pfinztal: Fraunhofer Institut für Chemische Technologie - ICT