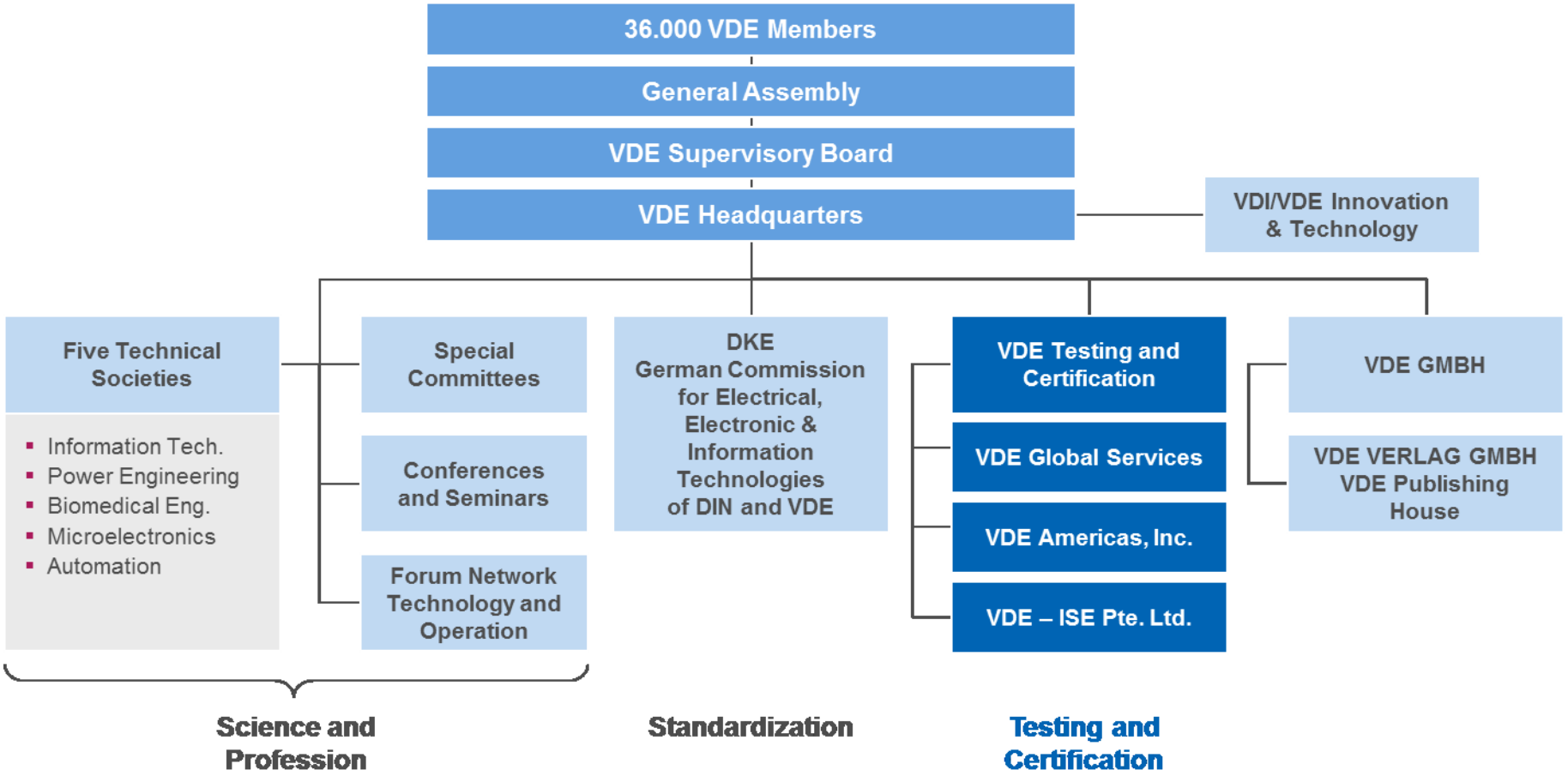
Supporting the deployment of safe Li-ion stationary batteries for large-scale grid applications

Test protocols

Christoph Borlinghaus,
VDE Testing and Certification Institute
Düsseldorf, 10 March 2015

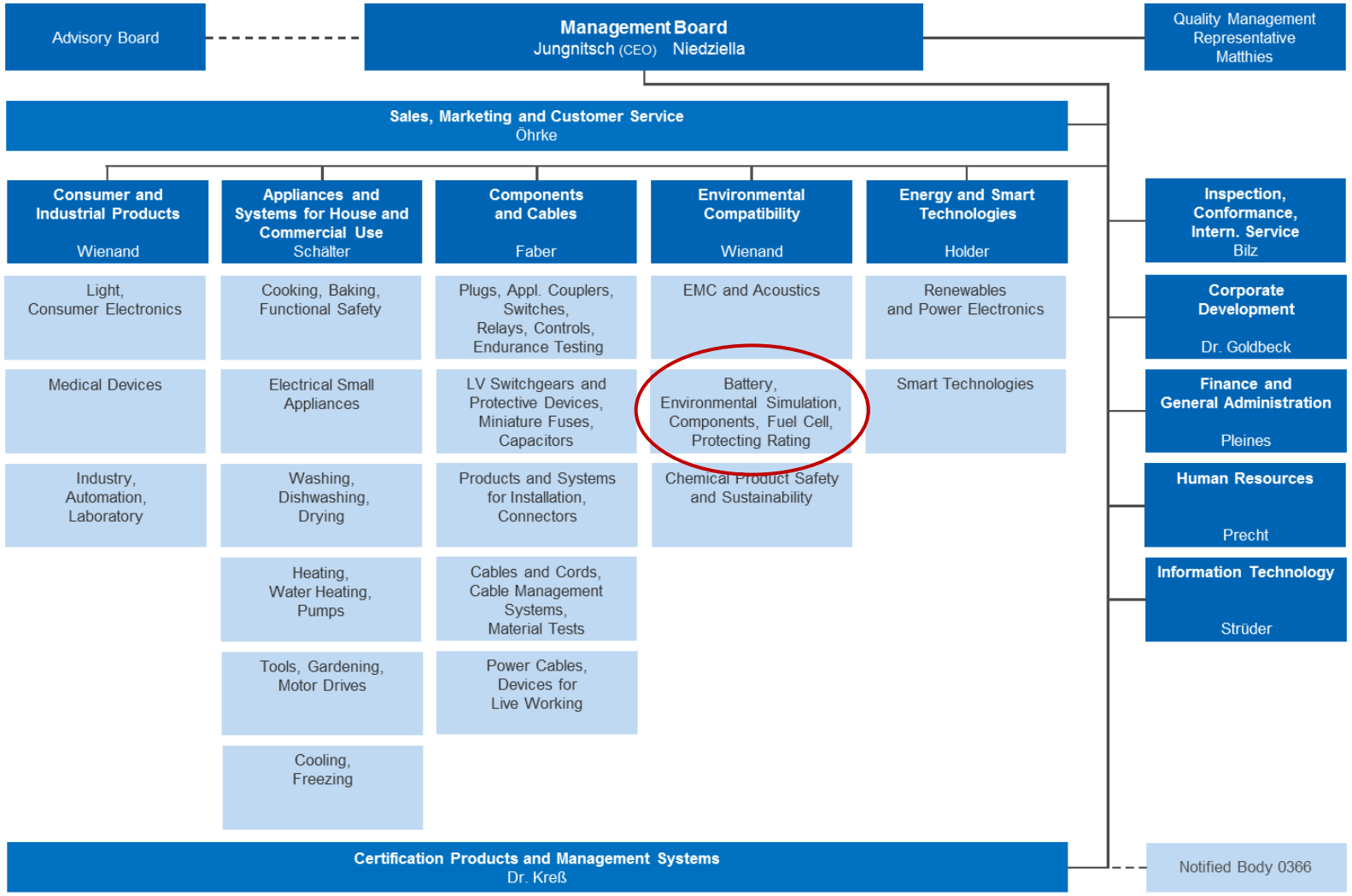
VDE

The information platform for electro technology



Organization Chart

VDE Testing and Certification Institute



Test planning within STALLION

safety tests for the evaluation of cells & test methods

» *feedback to standardization*

FMEA report

- fire ignition at cell level
- fire propagation at system level
- external/internal short circuit
- …

Test protocols

- new/standardized methods
- acceptance criteria
- …

DKE / IEC

VDE DIN

validation of new test methods

» *tests for risk mitigation available and sufficient?*
  - » *specificity*
  - » *sensitivity*
» *modifications needed?*

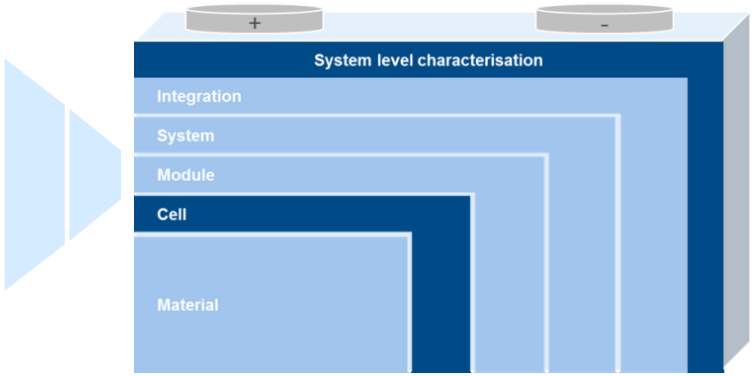
safety of cells

» *recommendation on cell types*

Test protocols

safety tests on module level

- BMS functionality test
- Module cycling without cooling
- External short circuit
- Overcharge
- Deformation
- Propagation of thermal runaway
- Rough handling of battery container



Test protocols

safety tests on cell level

overcharge		
10 °C	2 It	pressure
40 °C	It/2	~~pressure~~
Tmax	It	~~pressure~~

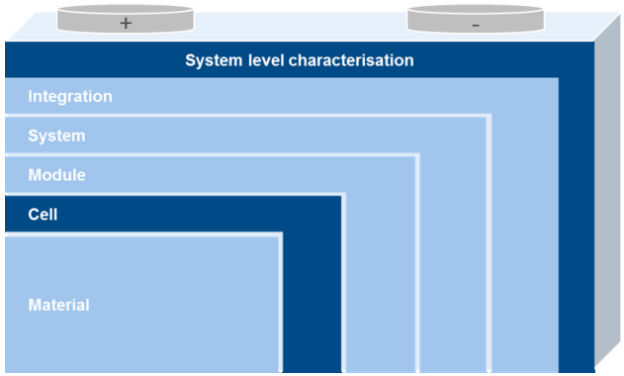
internal short circuit		
10 °C	Cu	2 mm/min
40 °C	PEEK	20 mm/min
25 °C	IEC 62660	10 mm/min

25°C	It
10 °C	It
40 °C	It/5

polarity reversal

10 °C	20 mΩ
40 °C	100 mΩ

external short circuit



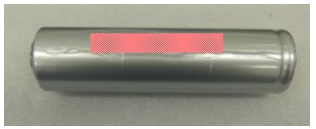
- *variation of standardized test parameters*
- *development of new test methods*
- *evaluation of cell safety*

LFP-C 40 Ah

NCO-LTO 16 Ah

LFP-LTO 20 Ah

LTO-NMC 9.4 Ah
LFP-C
NMC-C

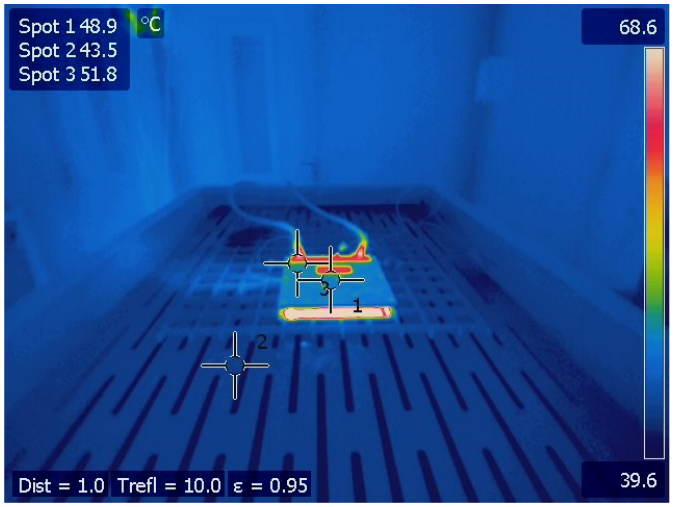


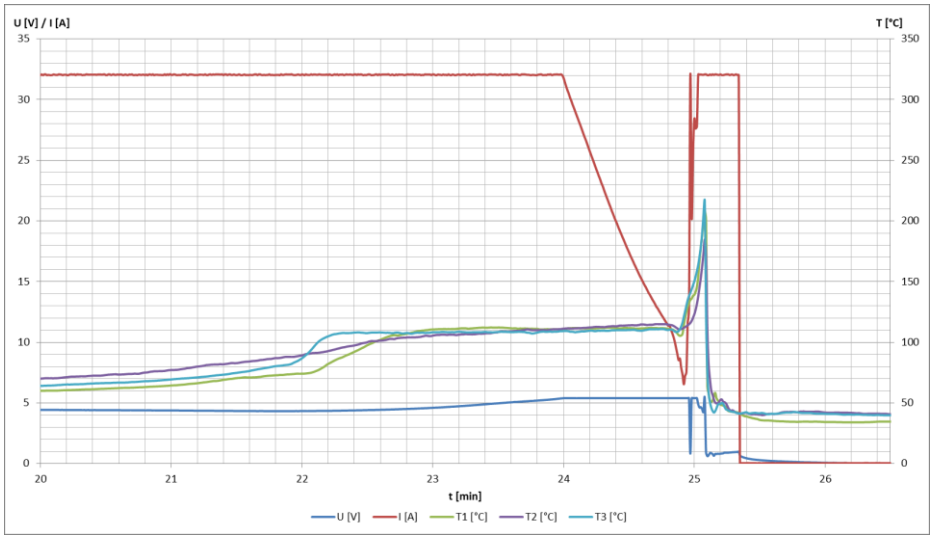
LiFePO4 15 Ah

Overcharge

outcome

- *higher temperatures* and
  higher charge currents increase the severity of hazardous events
- pressure device prevents inflammation – ignition source recommended
- thermal imaging useful to detect invisible venting activities



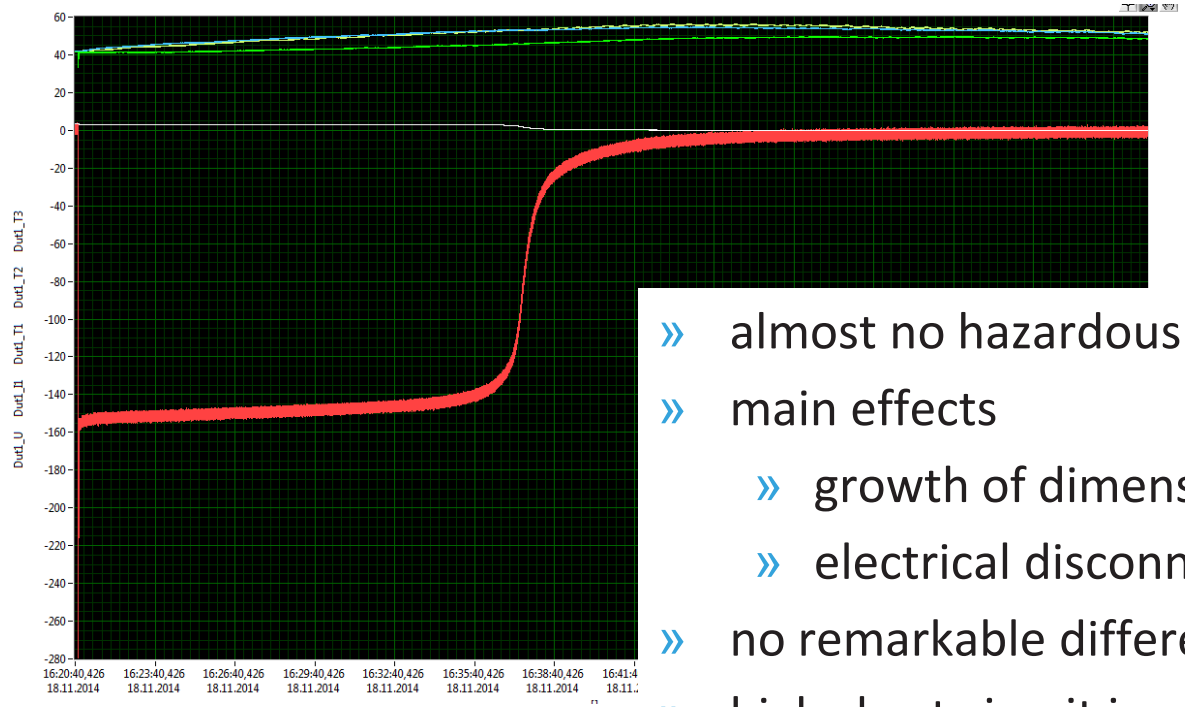


10 °C	**2 It**	**pressure**
40 °C	It/2	~~pressure~~
Tmax	It	~~pressure~~

recommendation

External short circuit

outcome



- almost no hazardous effects
- main effects
  - growth of dimension / inflation of casing
  - electrical disconnection
- no remarkable differences between 10°C / 40°C
- high short circuit impedances lead to
  - relatively low short circuit currents
  - low temperature increase during short circuit

10 °C	20 mΩ
40 °C	100 mΩ
40 °C	***≤ 5 mΩ***

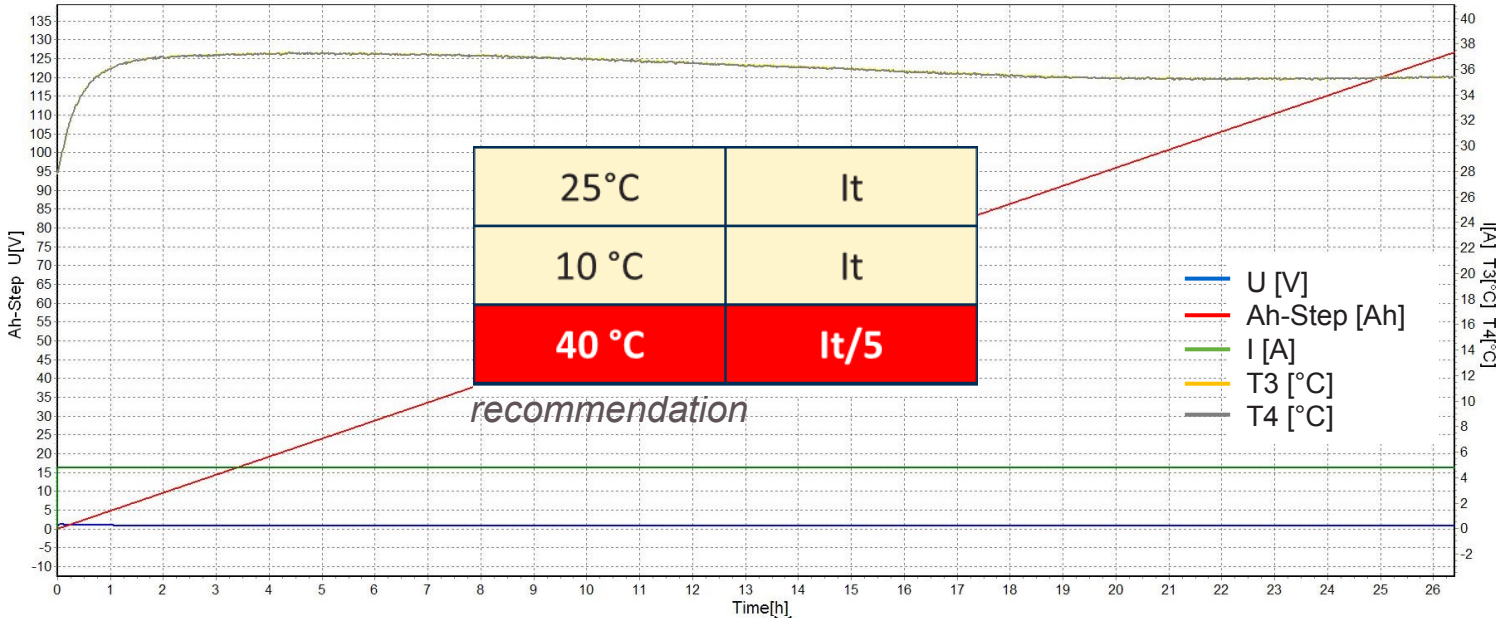
new

recommendation

Polarity Reversal

outcome

- main effects:
  - most of the cells prevent charging after reversal (only heating)
  - growth of dimension / inflation of casing
- *reversal effects (e.g. plating) are amplified by higher test temperatures caused by the decreased internal resistance of the cell;*



Internal short circuit

idea

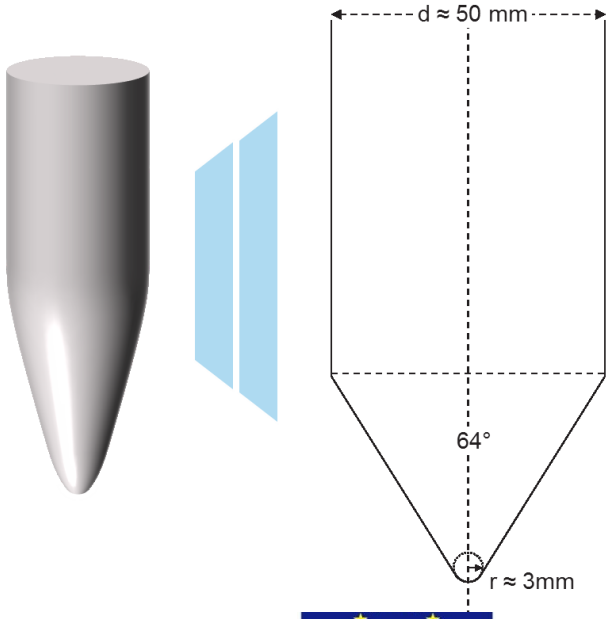
- simulation of internal short circuits by
  - penetration without piercing
  - exertion of external force on cell surface until breakdown of seperator
  - variations of test parameters
    - test temperature

      10°C | **40°C**
    - forward speed of tool

      2 mm/min | **20 mm/min**
    - material of tool

      PEEK | **Copper**

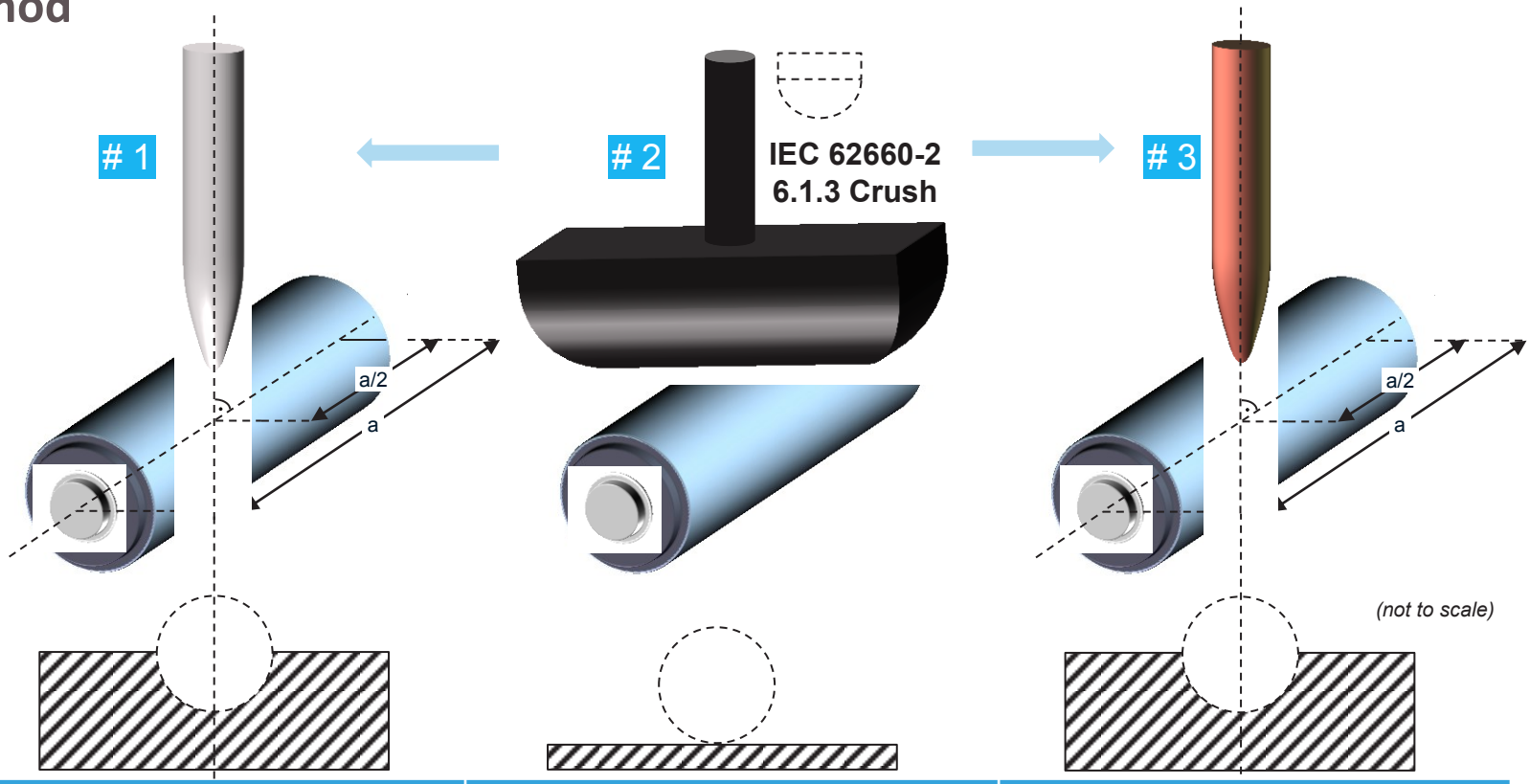
tool for both prismatic and cylindric cells



Internal short circuit

test method

cylindric cells

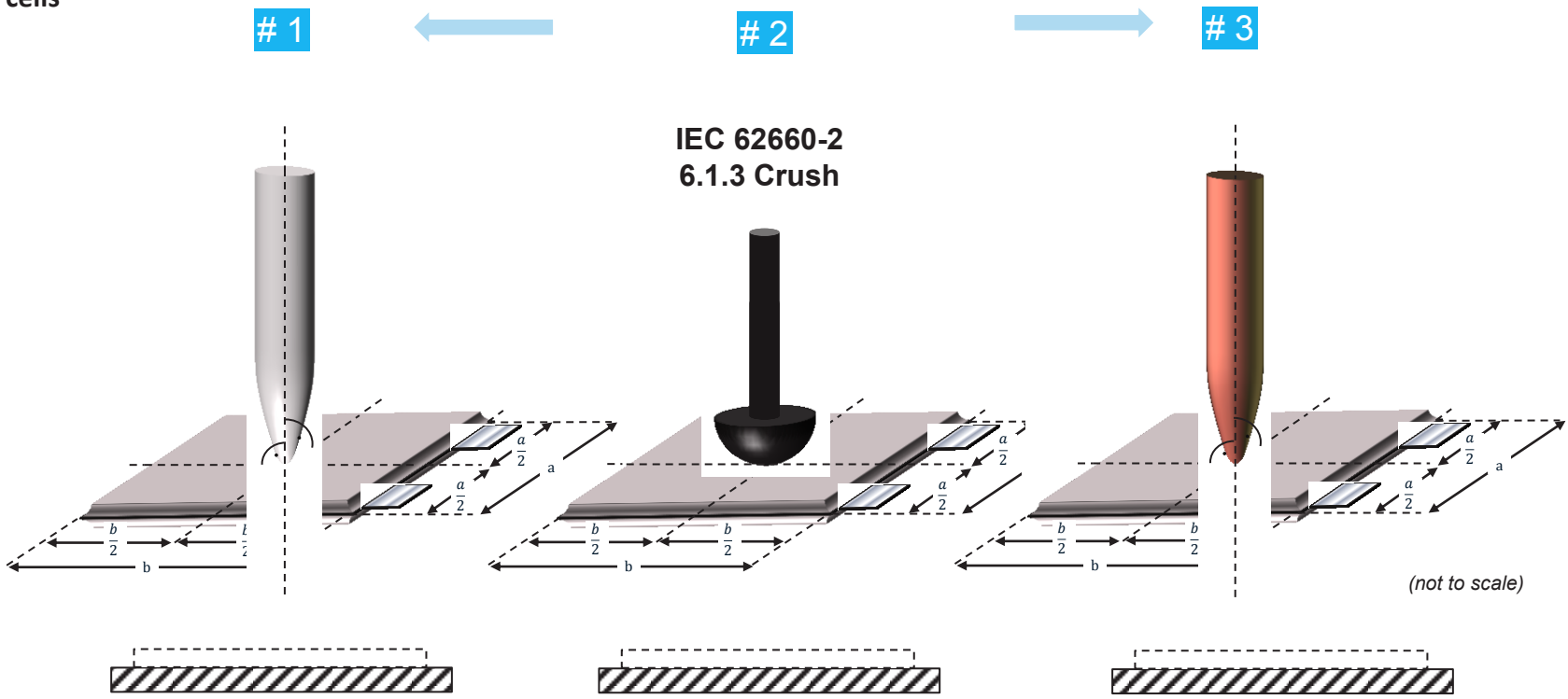


form / material	PEEK	round or semicircular bar comparable to diameter of cell / steel	Copper
area of exerted force		„nearly perpendicular to a layered face of positive and negative electrodes inside cell“	
purpose	Trough with semicircular notch comparable to diameter of cell to prevent any side effects of deformation of cell during penetration (delamination ect.)	Simulation of standard test procedure described in IEC 62660-2 6.1.3 Crush as feasability test of internal short circuit	

Internal short circuit

test method

prismatic cells



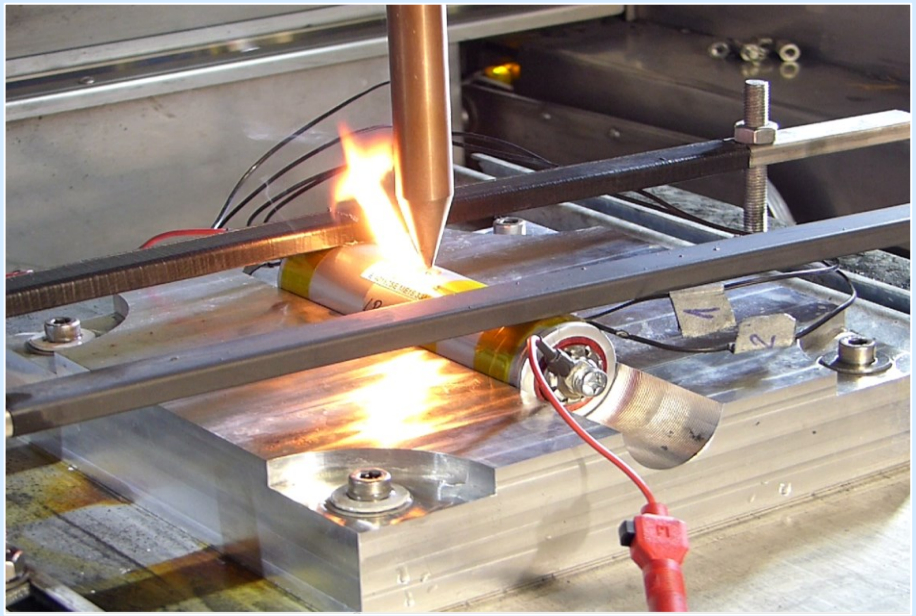
form/material	(same properties & conditions as #1 for cylindric cells)	hemisphere, 150mm diameter / steel	(same properties & conditions as #1 for cylindric cells)
area of exerted force		center of flat surface,	
purpose		Simulation of standard test procedure described in IEC 62660-2 6.1.3 Crush as feasability test of internal short circuit	

Internal short circuit

results (so far) - safety of cells

cell reactions:

- temporary ignition of cells
- melting of casing
- malfunction of venting device (premature release through fracture of casing)
- immense gaseous formation of electrolyte
- forceful pressure release and electrolyte spillage



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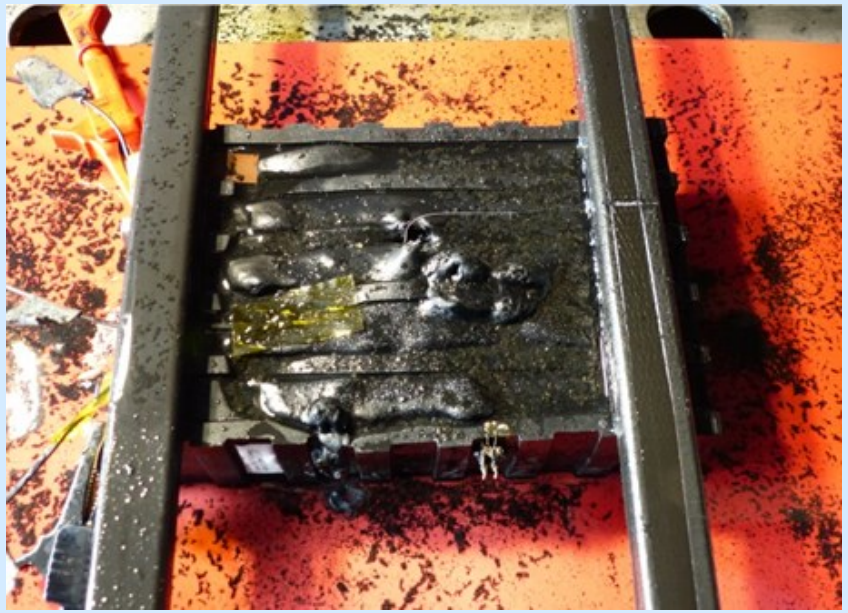

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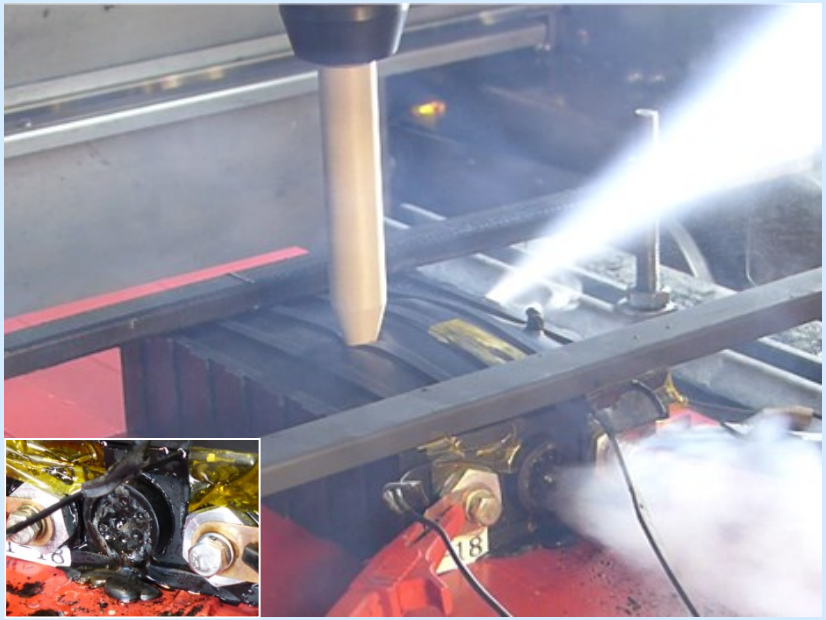

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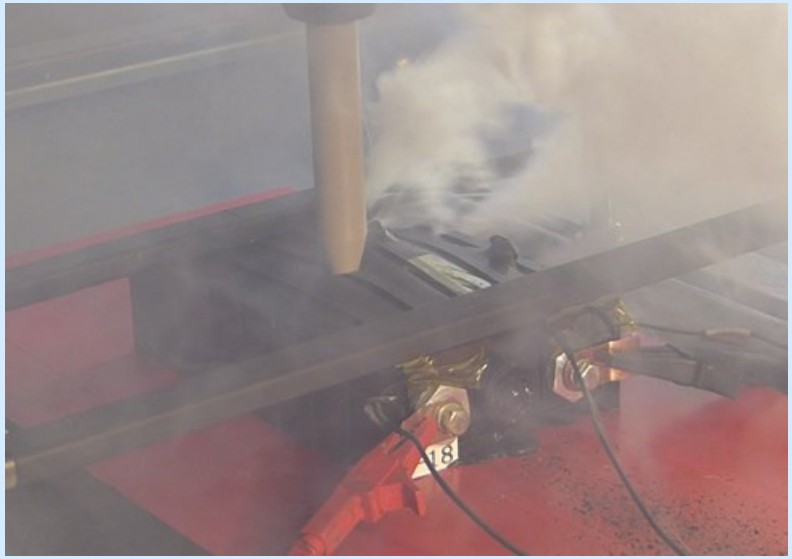

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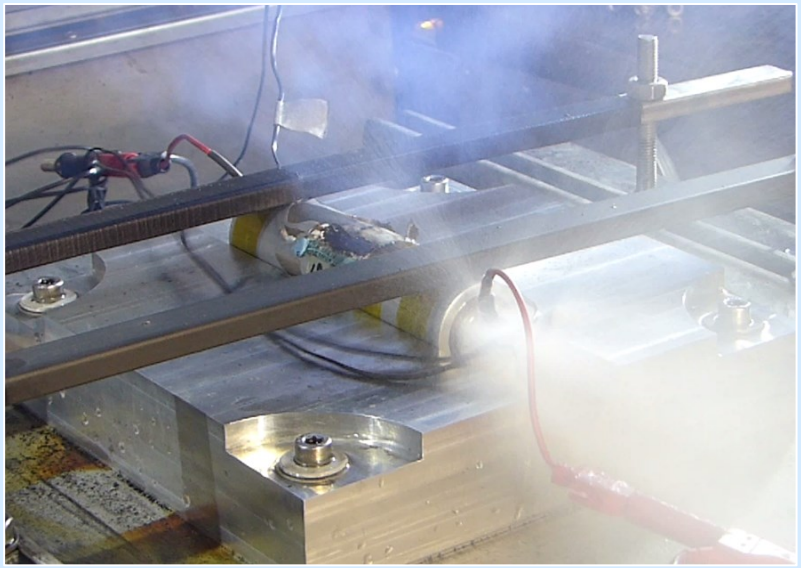
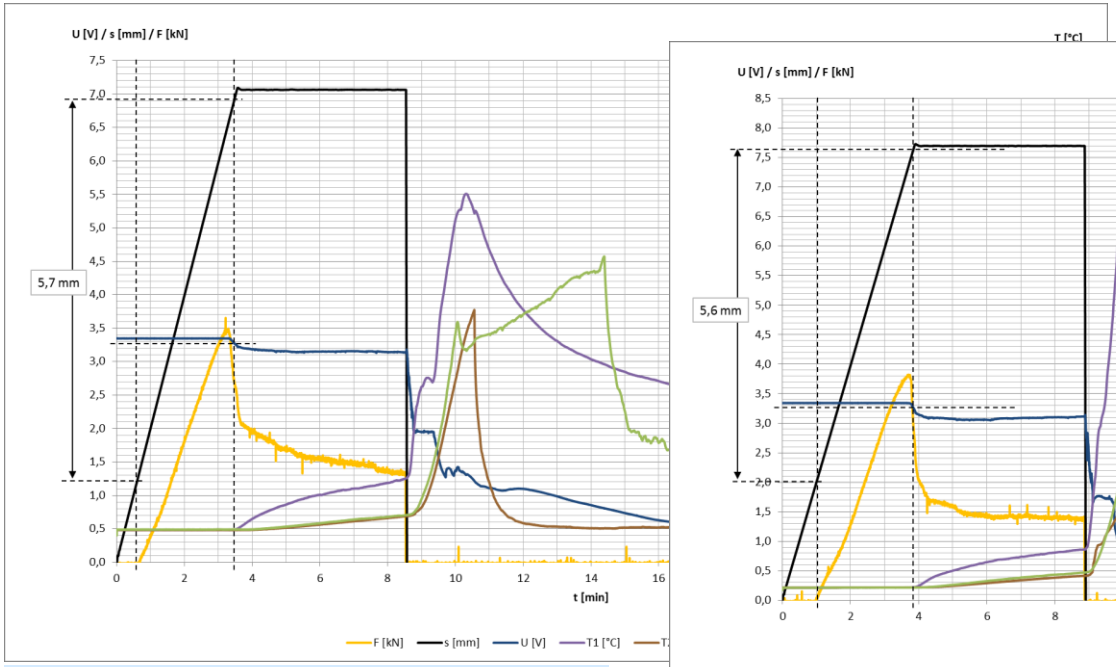


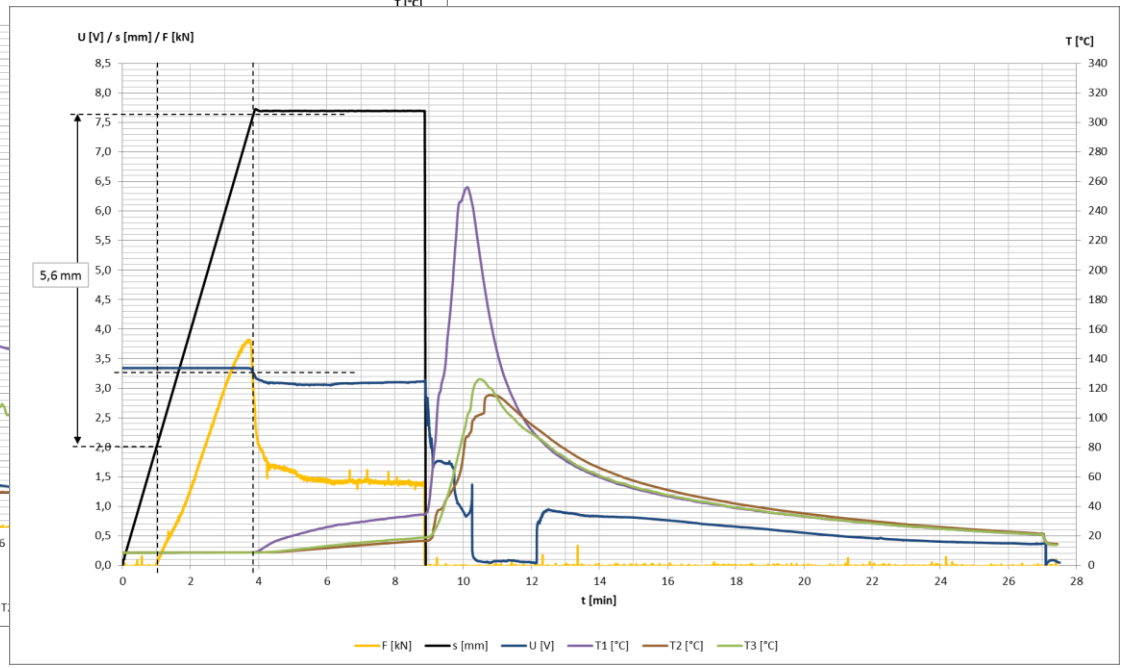
Internal short circuit

results (so far) – validation of test method

» *the test procedure itself is **repeatable** regarding displacement and force*



*example: 2mm/min, 10°C, Cu @ LiFePO4 cylindrical cell **(1)***



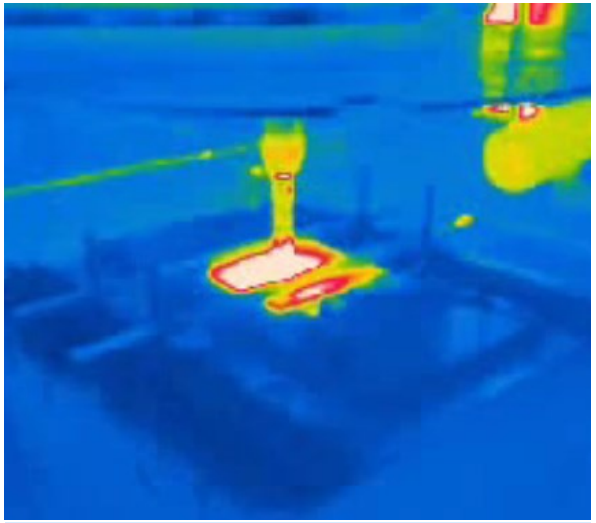
*example: 2mm/min, 10°C, Cu @ LiFePO4 cylindrical cell **(2)***

Internal short circuit

results (so far) – validation of test method

» *material of rod:* ***less heat dissipation with PEEK****, thus higher cell temperatures during ISC event*

example: ***PEEK rod***

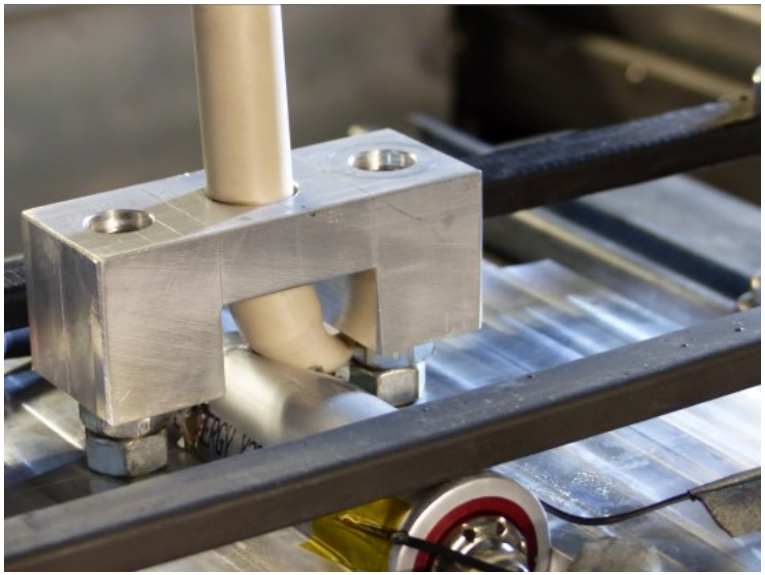


example: ***Cu rod***

Internal short circuit

results (so far) – validation of test method

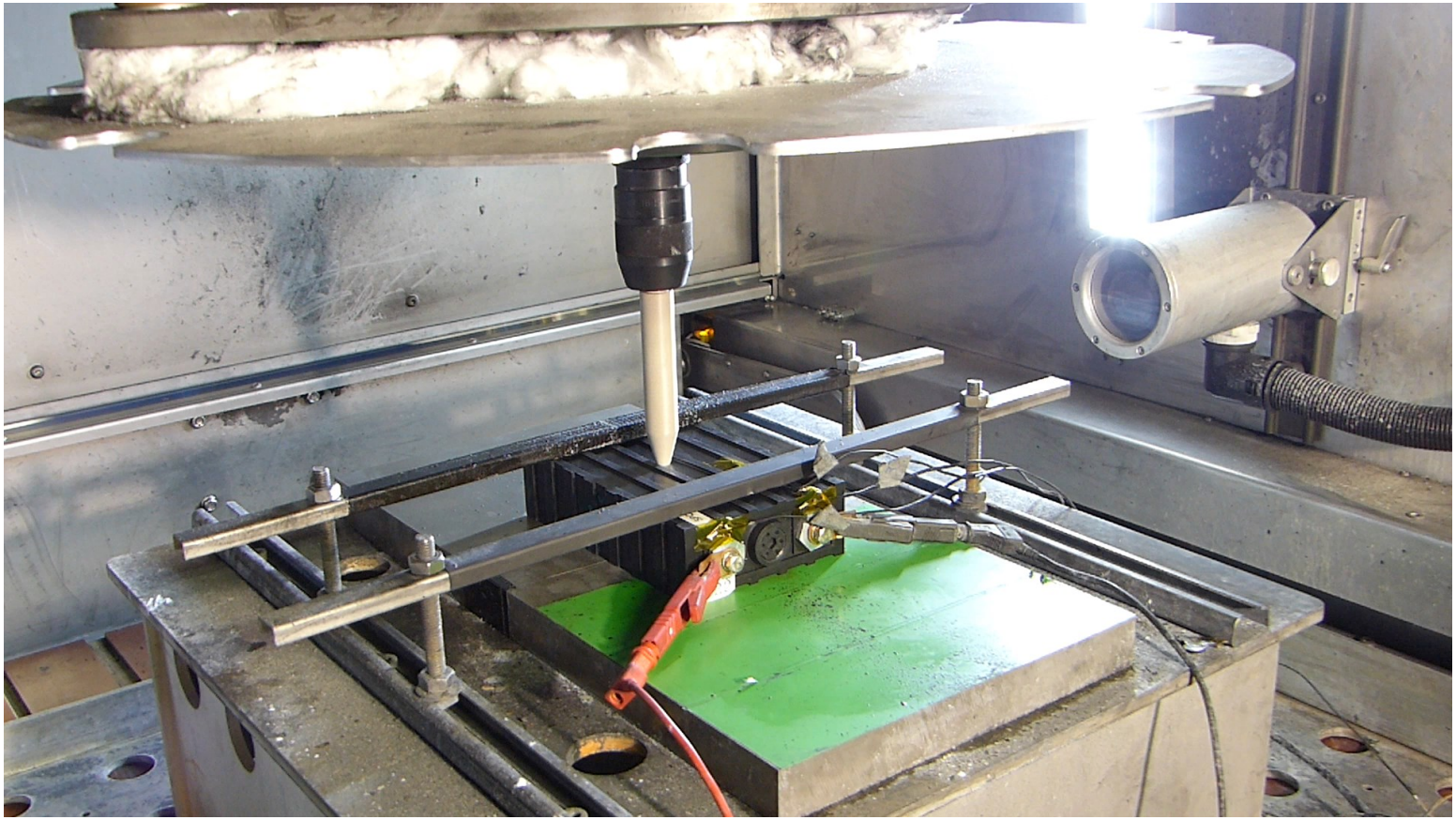
- *material of rod – **lessons learned**:*
  - *hard-plastic is generally to weak*
  - *Cu seems suitable for each kind of cell case material*
  - *PEEK is not applicable for cylindric steel cases*

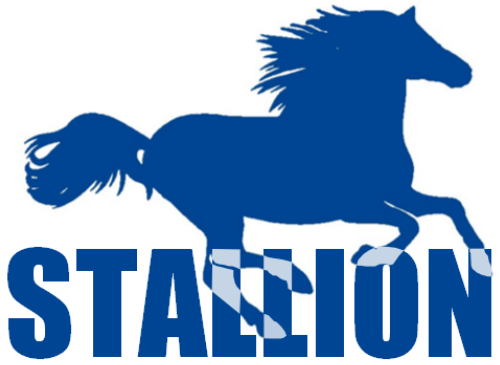


*(3) **PEEK rod with fence***

Internal short circuit

LFP-C – *40°C / 20mm/min / PEEK*





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Thank you!
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christoph.borlinghaus@vde.com

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