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AMI | Events
Plastics in Electric Vehicles
6-7 June 2023 | Munich, Germany

Safety of Electric Vehicles:

How the Right Choice of Polymers and Flame Retardants Can Help?

Cefic sector group

pinfa

Reiner is Head of Division R&D/Technical Service at Nabaltec AG. He is a polymer chemist by education and started his industrial career in Technical Service.

Since 2003 he has been holding several management positions within Nabaltec focusing on R&D, application technology, technical service and marketing & sales.

Reiner’s main fields of technical expertise are in polymer compounding, formulation and stabilization with a focus on functionality by mineral fillers, especially flame retardancy.

In his current position he is also responsible for innovation- & IP-management and R&D co-operations.

Cefic sector group

Notes and references

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Strong heat barriers by ceramifying flame retardants for EV battery housings

Dr. Reiner Sauerwein

Head of Division / R&D / Technical Service

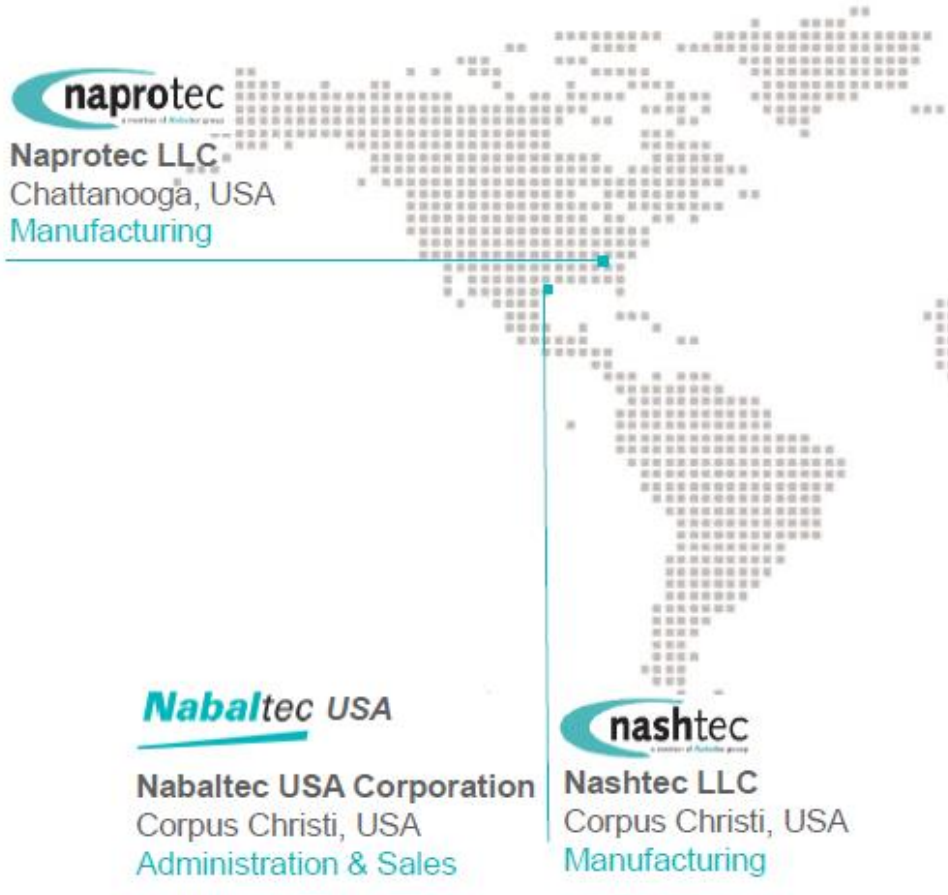
Nabaltec

Cefic sector group

The European Chemical Industry Council, AISBL – Rue Belliard, 40 - 1040 Brussels – Belgium
Transparency Register n°64879142323-90

Nabaltec at a glance

Nabaltec Group



Nabaltec AG
Schwandorf, GERMANY
Head Office

Naprotec LLC
Chattanooga, USA
Manufacturing

Nabaltec USA Corporation
Corporate Christi, USA
Administration & Sales

Nashtec LLC
Corpus Christi, USA
Manufacturing

Nabaltec (Shanghai) Trading Co., Ltd.
Shanghai, CHINA
Sales & Marketing

The company in brief

REVENUES 2022*	EBIT 2022*
EUR 218.8 MILLION	EUR 29.2 MILLION
EMPLOYEES 2022	**PRODUCTION SITES**
506	3

Sustainability and ESG developments

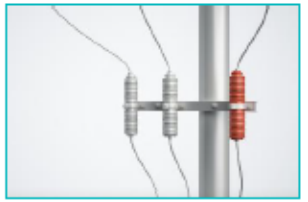
- Project on energy transformation started. Goal is to be CO_2 neutral by 2045
- Product Carbon Footprint based on Scope 1 & 2 available
- Calculation on PCF for Scope 1-3 will be finalized by QIV/23
- Double materiality analysis in progress. Finalization by July 2023
- An internal health management system implemented on top of the official ISO 45001 program
- Specific Company Carbon Footprint in kg CO_2 / (t of used raw material) could be reduced by 47% within the last 10 years.
- EcoVadis Gold Standard achieved in 2022
- Packaging: a test for using Supersacks partially made of recycled polymer in progress – customer feedback pending
- Project partner in recycling projects coordinated by PINFA

interzero®
zero waste solutions

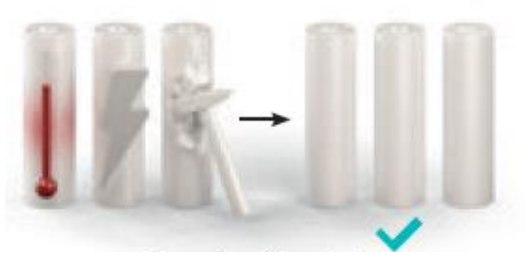
Recycling-Zertifikat
2023

Nabaltec AG
Alustraße 50 - 52
92421 Schwandorf

Product segments

Product segments	Functional Fillers 2022 revenues*: EUR 148.0 million		Specialty Alumina 2022 revenues*: EUR 70.9 million	
Product range	 $Al(OH)_3$	 $AlOOH$		
	Aluminum hydroxides	**Boehmites**	**Aluminum oxides**	**Ceramic bodies**
Properties	Eco-friendly, smoke-reducing, flame retardant, non-abrasive		Resistant to wear and tear, electrically insulating, resistant to corrosion, resistant to temperature changes	
Capacities**	Europe: 123,000 t Aluminum hydroxides 10,000 t Boehmites USA: 60,000 t Aluminum hydroxides		Europe: 72,000 t Specialty alumina	
Raw materials	Aluminum hydroxide		Aluminum oxide	

* preliminary figures; ** capacity based on product mix



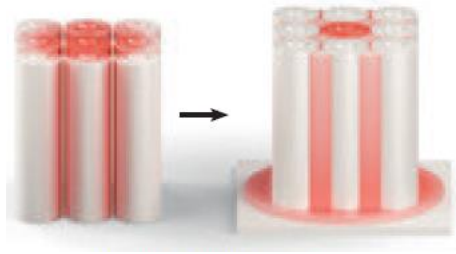
Prevention of short circuit

Battery Cell

AlOOH (Boehmite, AOH) used in CCS and electrode edge coating

Ceramic Coated Separators

APYRAL® AOH, ACTILOX®



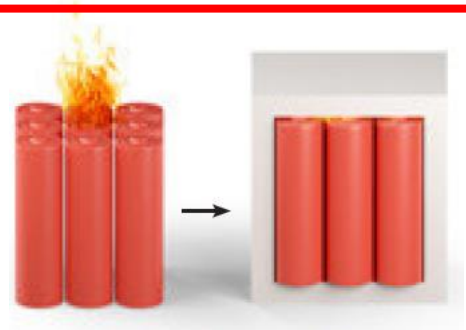
Prevention of thermal overload

Battery Module

$Al(OH)_3$ (ATH) used in TIM, gap fillers, adhesives, tapes

Thermal Interface Materials

APYRAL® HC, NABALOX® HC



Prevention of fire propagation

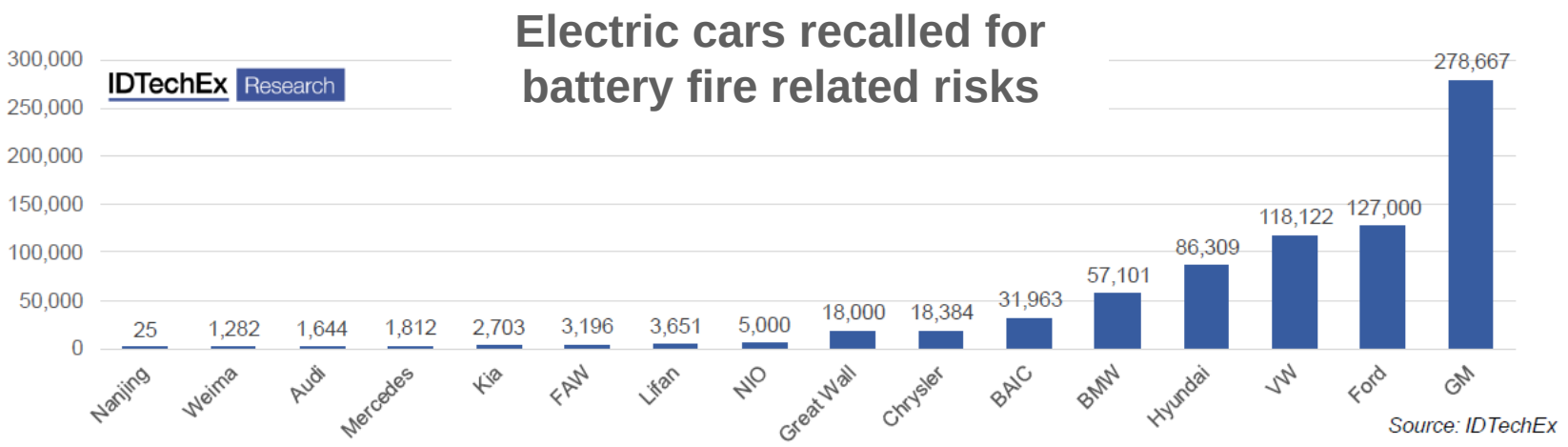
Battery Pack

Flame Retardant filler blends based on $Al(OH)_3$ (ATH) and AlOOH (Boehmite, AOH) as ceramifying HTB

Heat Temperature Barrier

ACTILOX® HTB

Motivation: Thermal Runaway and fires in EVs



E-mobility car fire, Landeck, October 2017

Photo: Freiwillige Feuerwehr Landeck

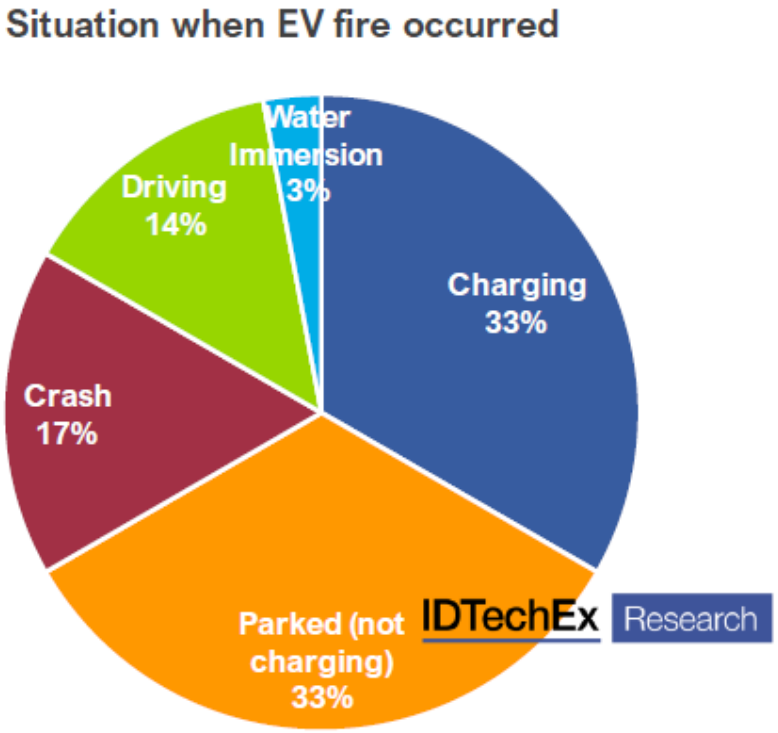
Many recalls have been issued relating to potential fires in EVs, the most prominent of which were the Hyundai Kona and Chevrolet Bolt recalls. These recalls were due to two concurrent faults in the cells provided by LG Chem, which caused a short and potential fire risk.

These recalls can be costly to the company's reputation, but also financially, with the GM recall of the Bolt estimatedat US$2 billion and Hyundai's Kona recall estimatedat US$900 million.

A Hyundai Kona caught fire whilst parked in a garage, leading to an explosion that took the roof of the building. Source: CleanTechnica.

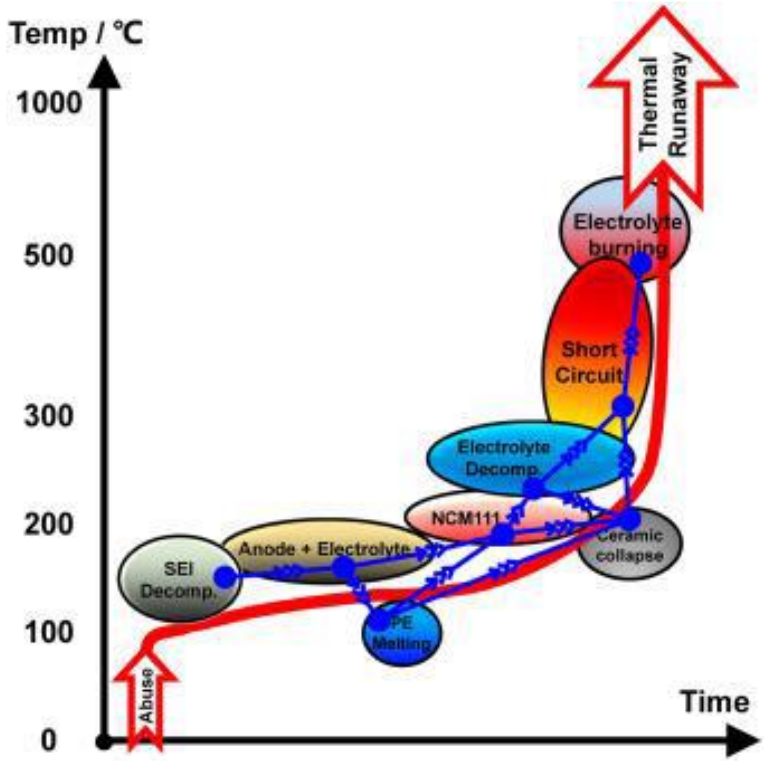
Source: Fire Protection Materials for Electric Vehicle Batteries 2023-2033, IDTechEX Research

Thermal Runaway Propagation – when (situation) & escalation



Analysis of 105 EV fires. The most common situations for EVs to catch fire is during charging or whilst parked (not charging or operating). Source: IDTechEx.

Challenge: Enclose the Heat & Gas during thermal runaway inside the battery as long as possible



Source: Feng, Xuning, et al. Energy Storage Materials (2017).

Regulations

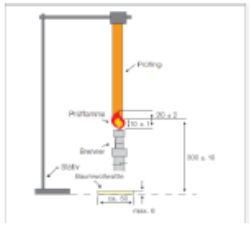
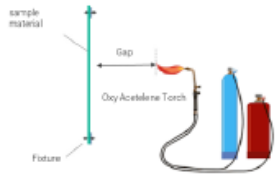
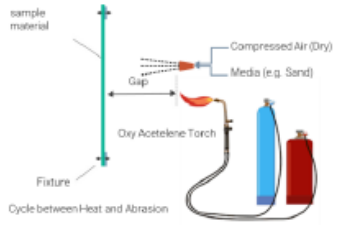
China is the first to mandate requirements specific to thermal runaway, but vehicles manufactured for other regions often comply with or try to exceed the Chinese standards.

China	Europe	US	Global
• Three mandatory standards relating to EV battery safety. • GB 38031-2020, GB 18384-2020, and GB 38032-2020. • Emphasize improvement to safety regarding vibration, mechanical shock, crush, thermal humidity cycling, water immersion, temperature shock, and salt spray. • A five-minute warning is required to occupants before a thermal event is observed outside the pack.	• UNECE R-100 Battery Regulation. • Includes various mechanical tests. • Thermal shock and cycling tests plus fire tests. • No cell level requirements. • Not fully integrated standard yet.	• Earlier stages for the US. The National Highway Traffic Safety Administration has established a battery safety initiative. • Looking to integrate the ECE GTR 20 regulation. • Participating in developing Phase 2 of the GTR 20 regulation.	• UN ECE GTR 20 EVS (United Nations Economic Commission for Europe Global Technical Regulation 20 on the Electric Vehicle Safety). • Established in 2012 with GTR 20 added in 2018; this standard is still evolving. • No external smoke, fire, or explosion outside the pack within five minutes of a thermal event. A warning is required at the onset of a thermal runaway event.

Intensive Development on test procedures by OEMs, suppliers and test-laboratories ongoing

„Severity cascade of testing“

Source: Forward Engineering

FLAME-TESTING	TORCH-TESTING	TORCH+MEDIA/ PYROTECHNIQUE
→ Temperature Resistance ✓ e.g. UL 94 V for plastics ✓ flame retardancy ✓ material integrity	→ Temperature Resistance ✓ >Thermal Load (>1000°C) ✓ flame retardancy ✓ material integrity	→ Temp + Ablative Forces ✓ flame retardancy ✓ material integrity ✓ surface wear
		
▪ Preliminary screening of sample materials' FR performance	▪ Screening of FR performance at more relevant thermal load ▪ Insulative Performance	▪ Incorporates abrasion resistance more representative of TRA event

Propagation / Thermal Runaway Test

Source: AZL Aachen GmbH

Ignitability & FR performance → ***+ heat barrier & material integrity*** → ***+ abrasion resistance (particles)*** → ***+ pressure build up in battery***

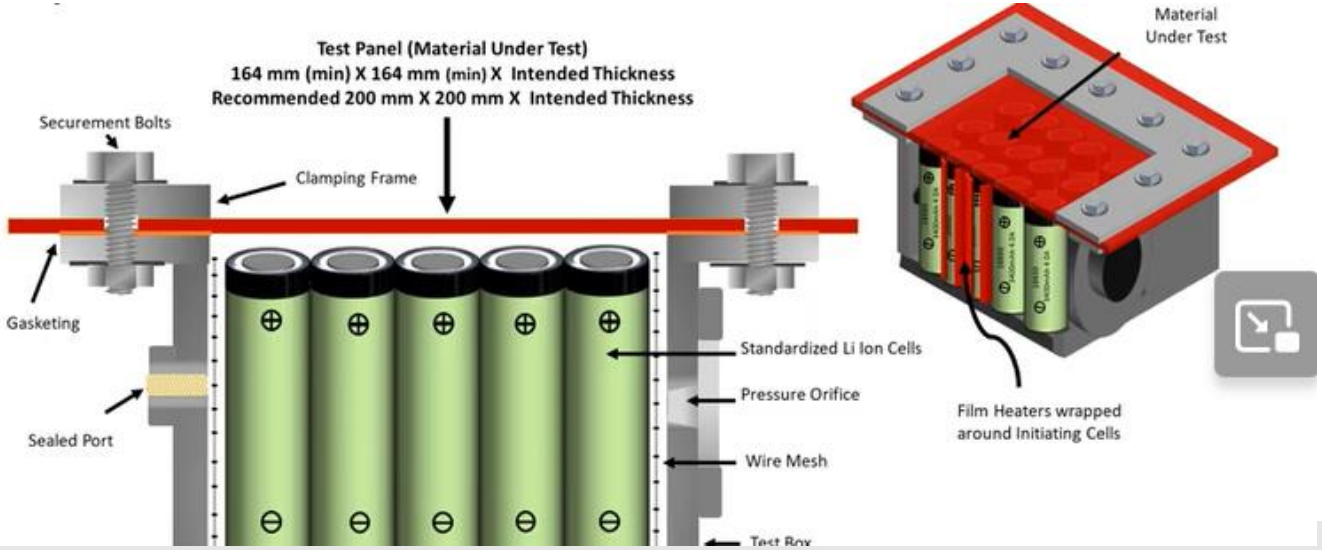
UL 2596 – Electric Vehicle Battery Enclosure Material Safety

- Objective:
  - Develop a material screening test that includes the dynamic stresses found in an actual automotive battery thermal runaway event.
    - High temperature
    - Abrasion due to battery particles propelled while cells break down and outgas.
    - Supplement to UL 2596 thermal runaway test without pressure component, but quicker to run.

„Torch“

„Grit“

Source: https://www.ul.com/resources/electric-vehicle-battery-enclosure-material-safety-ul-2596



TaG = Torch and Grit Test

- 15 sec 1200°C flame
- Followed by 5 sec flame and grit blast
- Cycle repeated until sample breaks

BETR = Battery Enclosure Thermal Runaway

- Thermal runaway triggered by heating cells
- Temperatures (inside, outside) and pressure inside battery is recorded

Available technologies /material solutions

Fire protection materials: main categories

IDTechEx

Cell-level

Pack-level

Encapsulants

Compression pads with fire protection

Aerogels

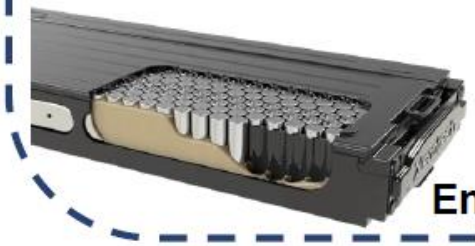
Coatings

Intumescent coatings

Phase change materials (PCMs)

Mica sheets

Ceramic papers/ blankets/ sheets



Encapsulating foams

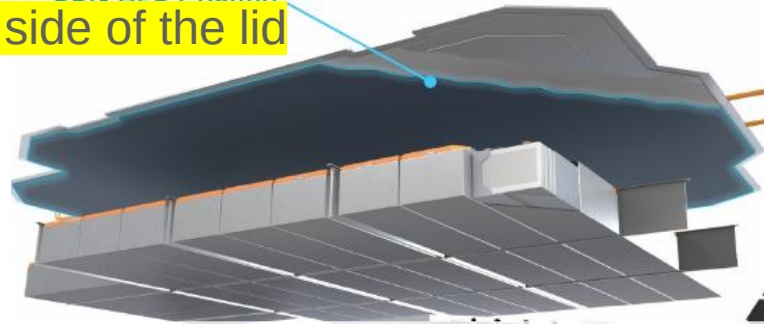
Source: Fire Protection Materials for Electric Vehicle Batteries 2023-2033, IDTechEX Research

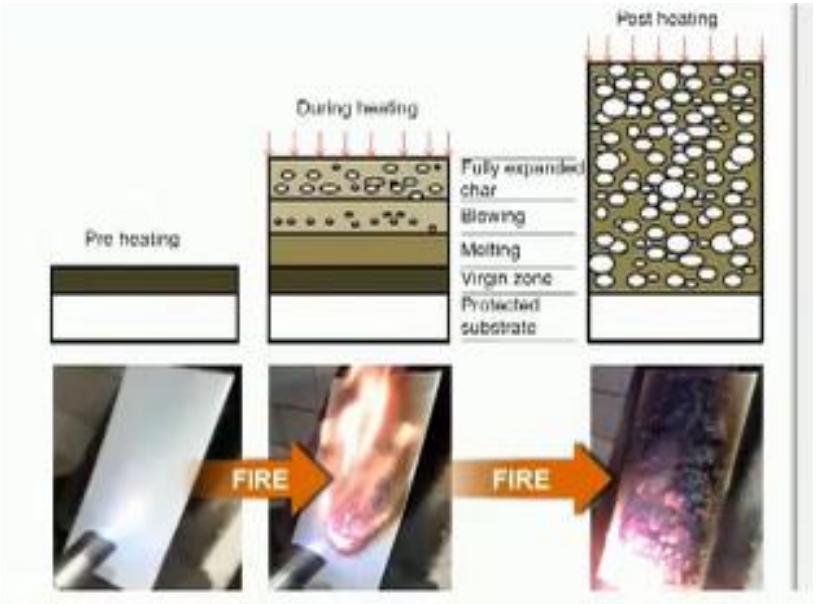
Mica sheets and protective coating – most common „state of the art“ today

In **VW’s MEB platform** (used for ID3, ID4, and other upcoming models), we see the application of mica sheets on top of each of the battery modules.

„Add-on“ protective *mica sheets and fire retardant* ***barrier*** *coatings are dominating, but* ***require additional assembly step!***

Fire protection coating on inner side of the lid

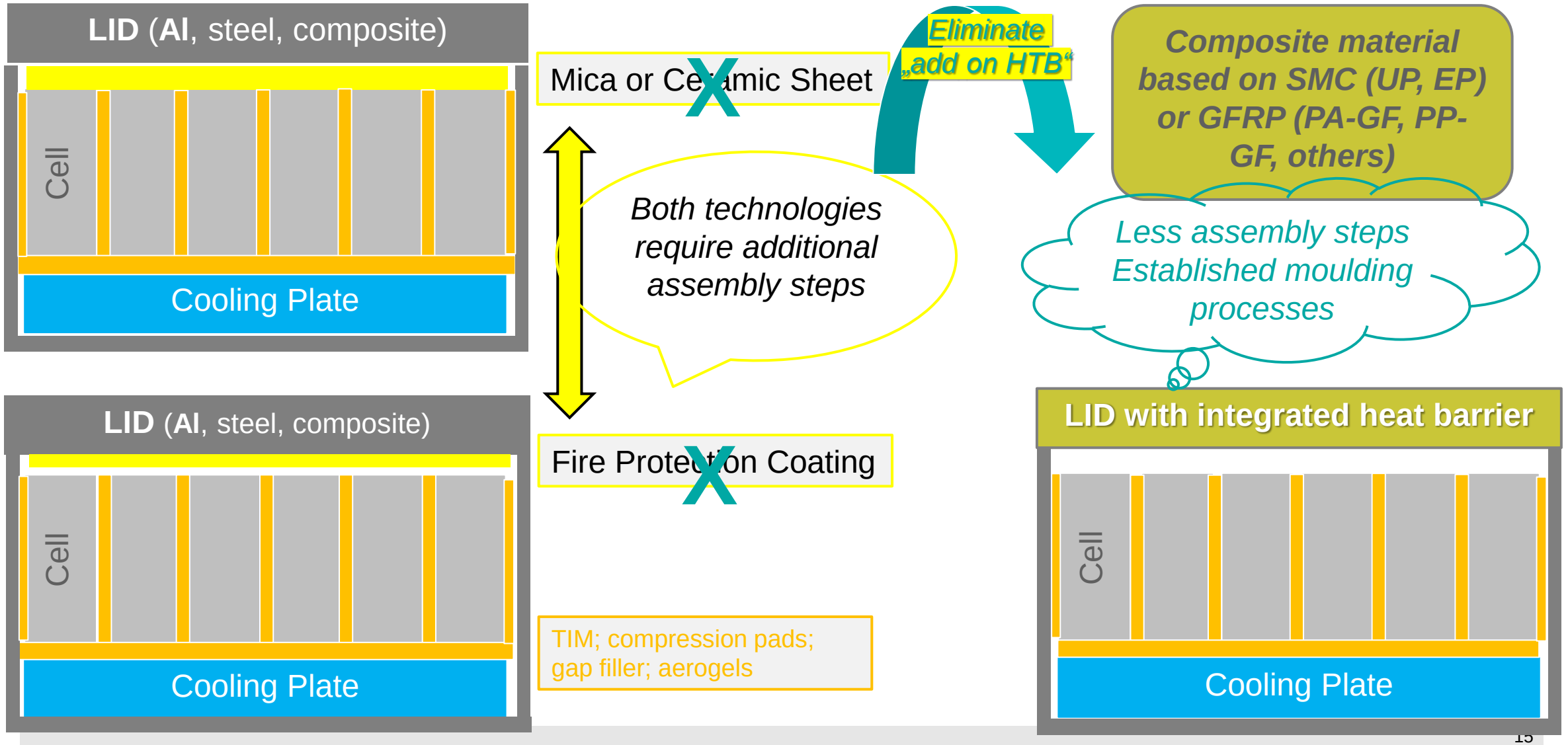




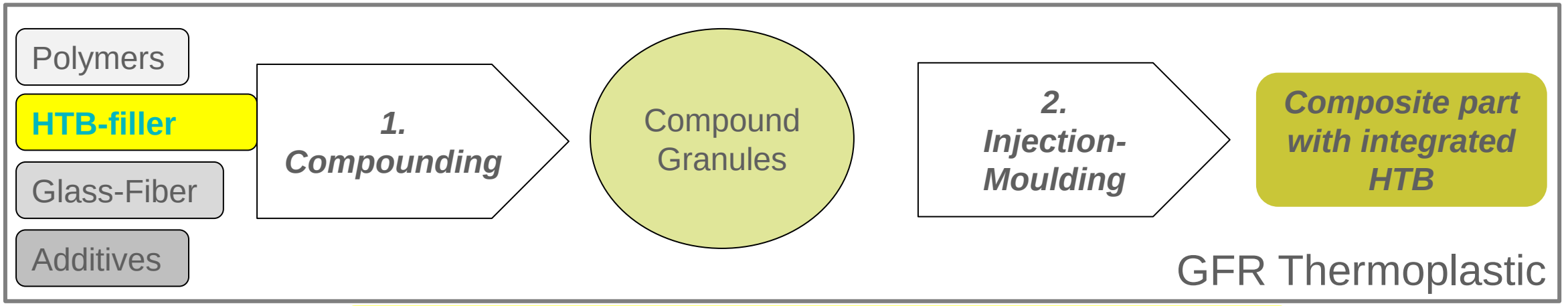
Source: Fire Protection Materials for Electric Vehicle Batteries 2023-2033, IDTechEX Research

Source: PPG

Alternative material concept for lid – Heat Barrier integrated in composite part

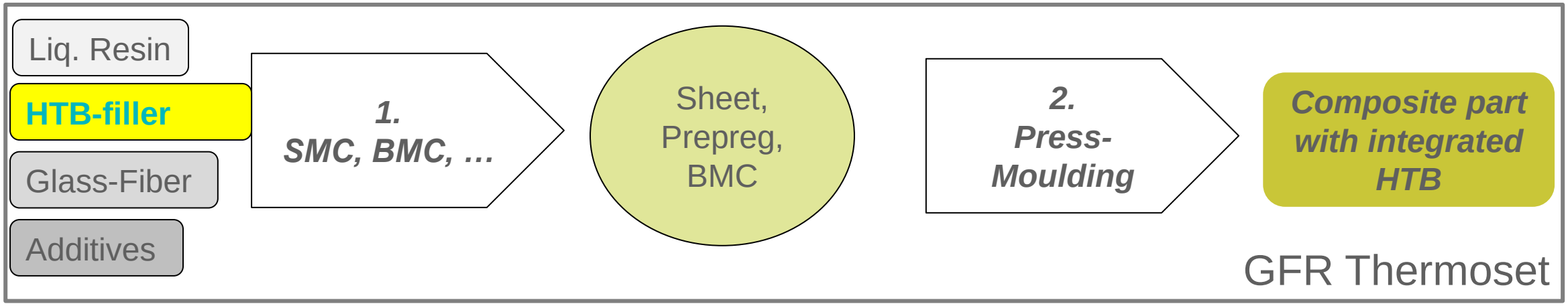


Two step process with ACTILOX HTB



ACTILOX HTB ; Heat Temperature Barrier

- **proprietary ceramifying flame retardant filler blends**

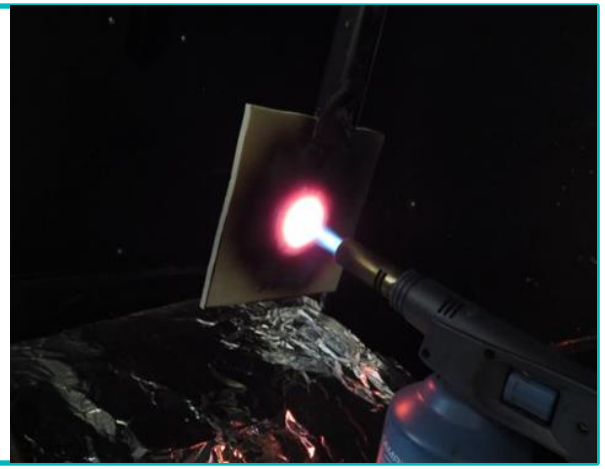


Nabaltec material test set up

Horizontal Torch Test

- *Plaque-specimen 10-15 cm x 10-15 cm*
- *Propan/Butan flame,*

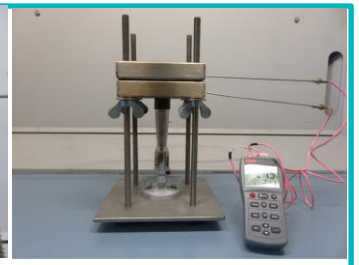
  1650 Watt, 90° angle, 5 cm distance → 1000 - 1200 °C
- *Temperature on front & back side measured by IR-thermometer*
- *Determination of time to penetration (burn through)*



Vertical Torch Test

- *Plaque-specimen 10 cm x 10 cm*
- *Propan/Butan flame,*

  1650 Watt, 90° angle, 5 cm distance → 1000 - 1200 °C
- *Temperature on front & back side measured by IR-thermometer*
- *Determination of time to penetration (burn through)*
- *Loading of test plaque on back side with weight (to simulate particle impact)*



UP resin – lab procedure

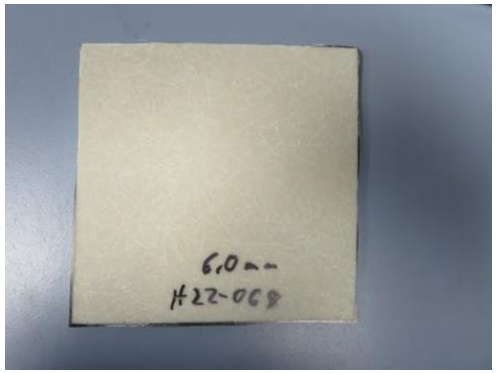
Resin Mix

100 phr UP-resin
1 phr MEKP (hardener)
200 – 300 phr filler

Hand lamination

85 – 87 wt.-% Filled UP
15 – 13 wt.-% Glass fiber matt

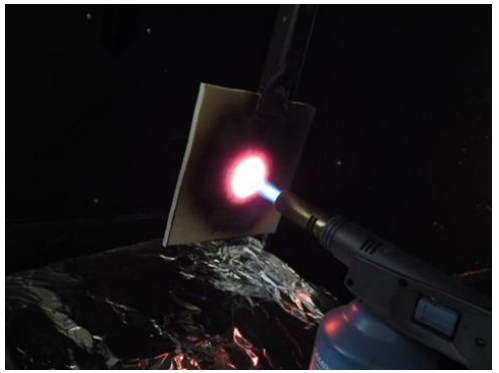
- *5 – 7 mm plaque specimen*



Horizontal Torch test

Plaque 10-15 cm x 10-15 cm
Propan/Butan flame, 1650 Watt, 1000 - 1200 °C

- *T on front & back side by IR*
- *Determination of time to penetration (burn through)*



Goals of test

➲ no cracks, no holes, no burnthrough

APYRAL 20X, 160phr
no glass fiber

pure ATH

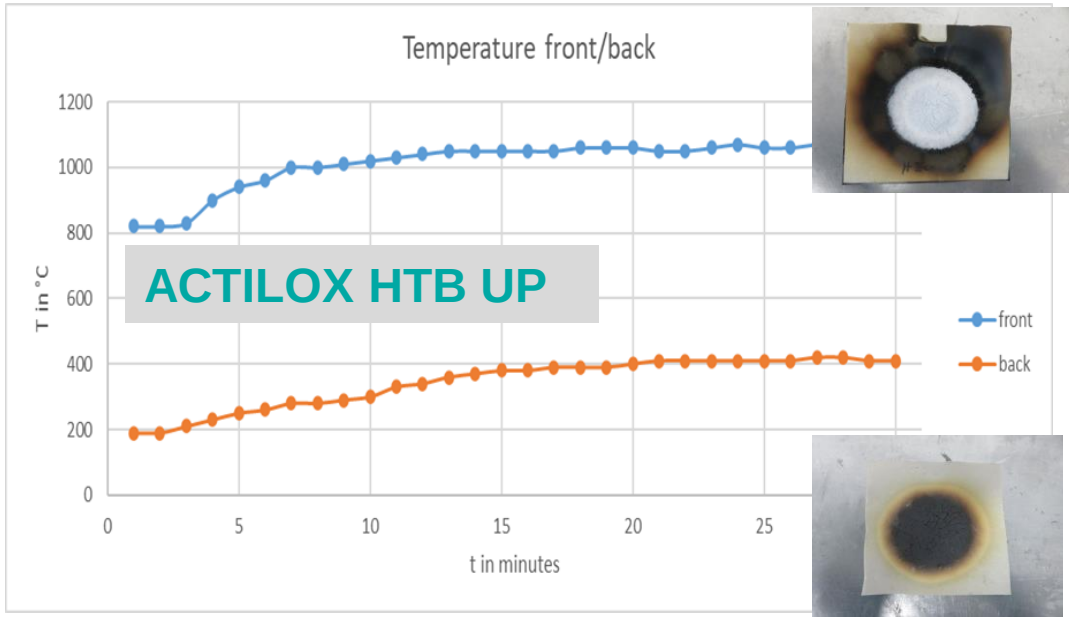
APYRAL 20X, 300phr
laminate

„fluffy“ residue / loose glass fibers

very solid ceramic like residue

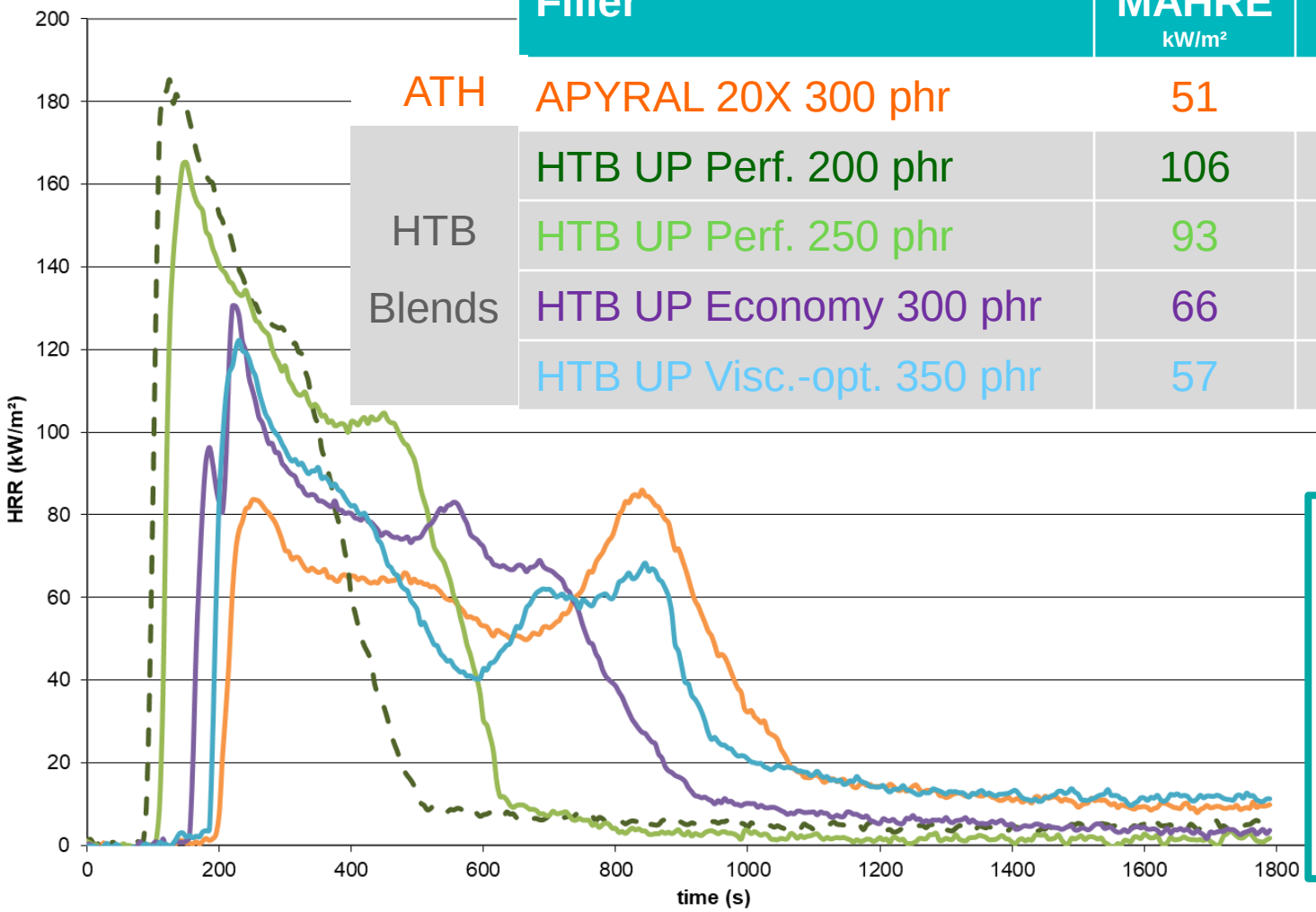
ACTILOX HTB UP, 200 phr
laminate

➲ max. 400°C (as long as possible)



- > 30 min no cracks or holes
- Max. 400 °C on back side
- No expansion (no intumescence)
- **Solid ceramic residue**

Cone Calorimetry



	Filler	MAHRE kW/m²	HL kW/m²	Railway EN 45545-R7
ATH	APYRAL 20X 300 phr	51	3	☺
HTB Blends	HTB UP Perf. 200 phr	106	1	☹
	HTB UP Perf. 250 phr	93	1	☹
	HTB UP Economy 300 phr	66	2	😐
	HTB UP Visc.-opt. 350 phr	57	3	☺

Good Heat Barrier / Shíelding does not neccessarily correlate with low Heat Release – pure ATH performs best!

- ***Which product to be used depends on test requirement in end application and test regime requested!***

PP resin – lab procedure

Compounding

22.5 wt.-% PP
65 wt.-% filler
12.5 wt.-% Glass fiber

Press moulding

- *10 cm x 10 cm*
- *3 – 4 mm thick plaque specimen*

Vertical Torch test – no weight

Plaque 10 cm x 10 cm
Propan/Butan flame, 1650 Watt, 1000 - 1200 °C

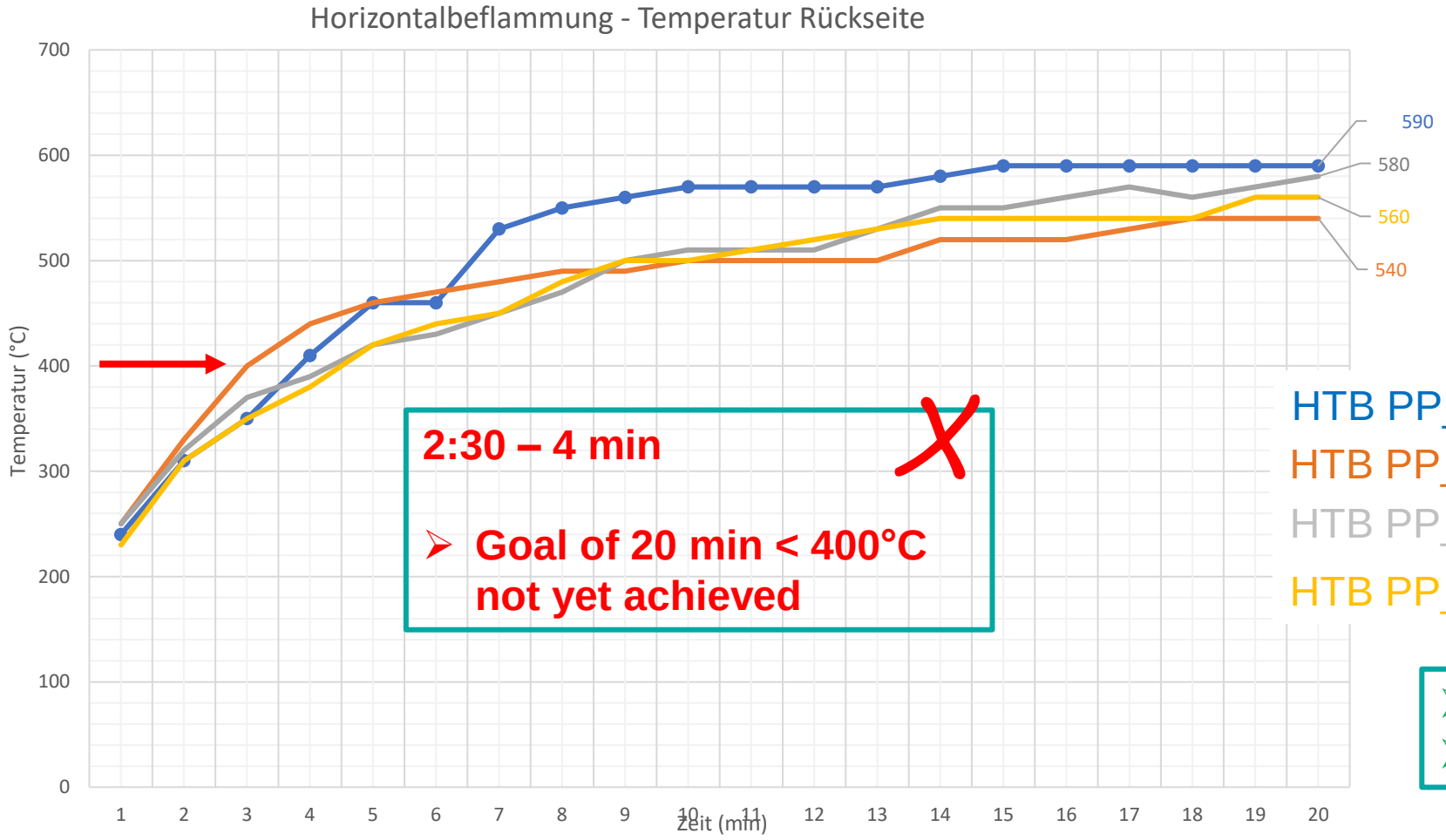
- *T on front & back side by IR*
- *Determination of time to penetration (burn through)*

Vertical Torch test – with weight

Plaque 10 cm x 10 cm
Propan/Butan flame, 1650 Watt, 1000 - 1200 °C

- *T on front & back side by IR*
- *Determination of time to penetration (burn through)*
- ***Loading of test plaque on back (upper) side with weight** (simulate particle impact)*

PP - Vertical Torch Test without weight

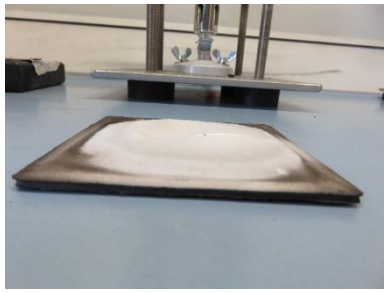


2:30 – 4 min

- **Goal of 20 min < 400°C not yet achieved**

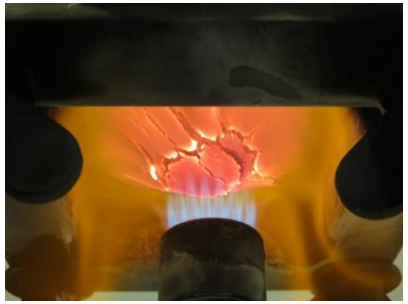
HTB PP_1-23

Specimen after test



- **No hole / burn through**
- **Solid ceramic residue**

PP - Vertical Torch Test with weight



	MVR (in cm³/10min @230°C / 10 kg)	Weigth in p 0.3 kPa	Weight in p 1.0 kPa	Weigt in p 1.7 kPa
HTB PP_1-23	0	> 10 min	> 10 min	> 10 min
HTH PP_2-23	2.4	> 10 min	> 10 min	1 min
HTB PP_3-23	8.7	> 10 min	> 10 min	1:30 min
HTB PP_4-23	5.5	5 min (?)	> 10 min	1 min

- **The higher the MVR, the more difficult it is to pass Vertical Torch Test under stress!**
- **Solidification of ceramic in the center of flame is fine**
- **…but softening of composite not directly exposed to torch-flame needs to be controlled**
- **doable and solved for thermosets**
- **…but challenging for thermoplastics**

Summary

- ACTILOX HTB are ceramifyable flame retardant filler blends adjusted to polymer matrix …
- …building stable heat barriers during torch flame tests requested by automotive OEMs

- ACTILOX HTB fillers enable composite battery housings / covers / lids with „integrated heat barrier“…
- …eliminating the need for additional heat barriers and assembly steps
- …delaying / preventing thermal runaway of battery packs

- ACTILOX HTB concept can be transfered to other high-severity fire protection applications…
- …but formulations need to be adjusted according to test requirements (heat barrier versus heat release)

- ACTILOX HTB filler composition-optimizations for thermoplastics are in progress…
- …adjustments according to specific requirements (thermosets & thermoplastics) will be done in close cooperation with customers

Nabaltec products make many aspects of everyday life safer, as well as being eco-friendly and an irreplaceable part of your daily routine.

Thank You for your Attention

Dr. Reiner Sauerwein
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Thank you.

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About Cefic

Cefic, the European Chemical Industry Council, founded in 1972, is the voice of large, medium and small chemical companies across Europe, which provide 1.2 million jobs and account for 15% of world chemicals production. Cefic members form one of the most active networks of the business community, complemented by partnerships with industry associations representing various sectors in the value chain. A full list of our members is available on the Cefic website.
Cefic is an active member of the International Council of Chemical Associations (ICCA), which represents
chemical manufacturers and producers all over the world and seeks to strengthen existing cooperation with global organisations such as UNEP and the OECD to improve chemicals management worldwide

Cefic sector group

The European Chemical Industry Council, AISBL – Rue Belliard, 40 - 1040 Brussels – Belgium
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