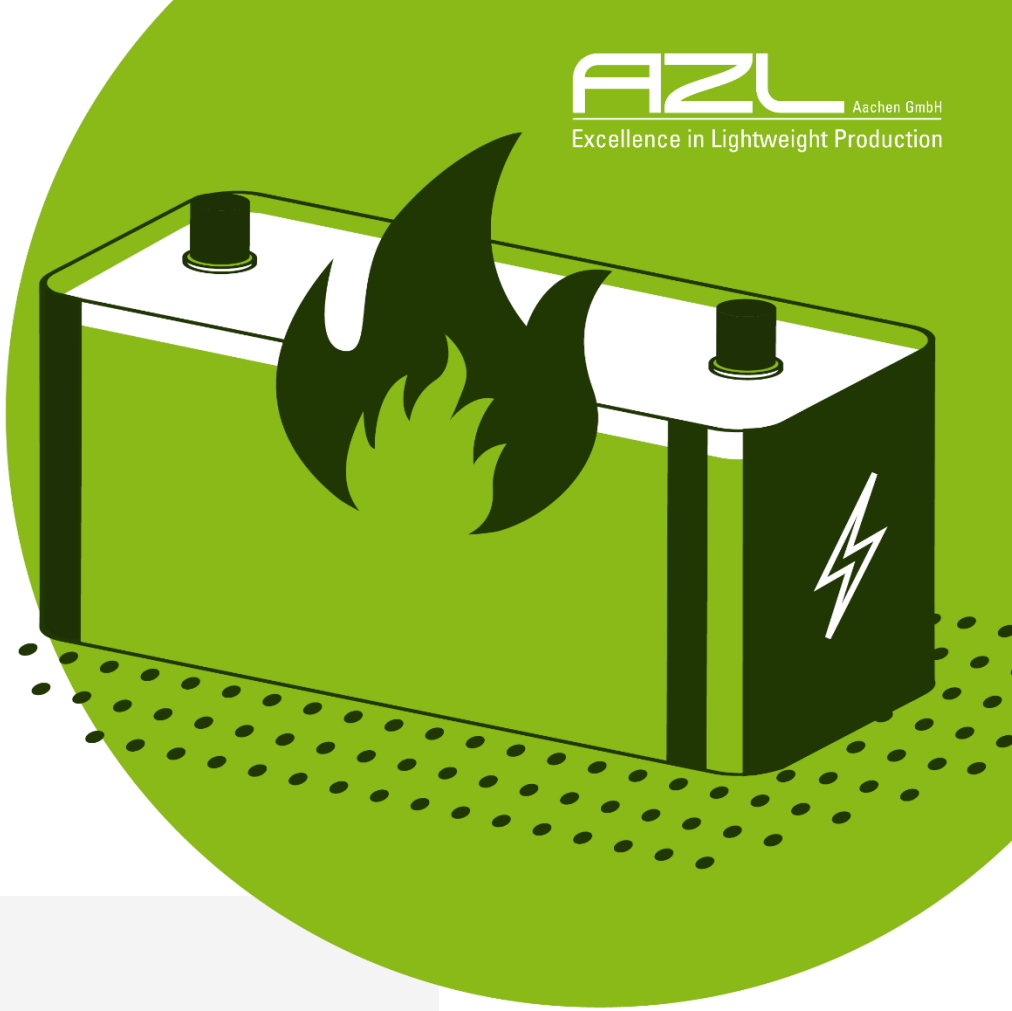
AZL Aachen GmbH
Excellence in Lightweight Production



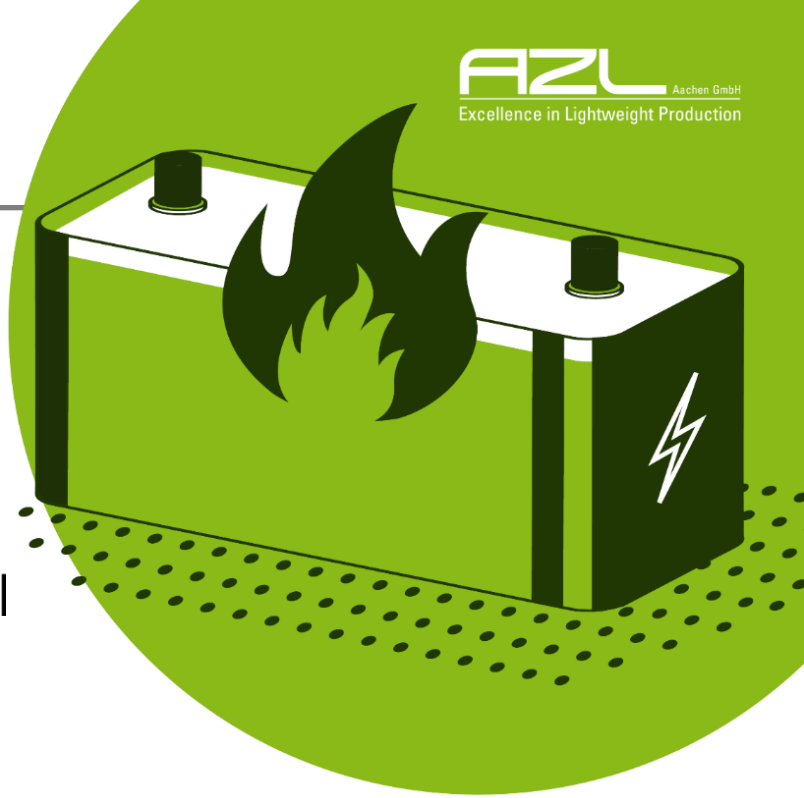
AZL Joint Partner Project:

Thermal Runaway Testing for Battery Casings

Benchmarking systems for high-gradient heating and hot particle blasting for fire testing of housing and functional materials for EV battery casings

Thermal Runaway Testing for Battery Casings

Join the consortium!



aperam

autoneum

HUTCHINSON®

MITSUBISHI CHEMICAL GROUP

Nabaltec

posco

TRINSEO

+ Anonymous

Background: Thermal Runaway Testing for Battery Casings
Regulations

- **GB 38031-2020: Needs a 5-minute warning before fire or explosion** for safe passenger exit. Applies to cells, modules, packs, and vehicles.
- **ECE R100 (Rev3):** After detection of a thermal runaway event, notified to the car driver, there should be a 5 minute safe escape time, without having a hazardous situation for the car passengers
- **ECE GTR 20 Addendum: Also requires a 5-minute warning before thermal hazards** that could harm vehicle occupants.
- **GB 38031-2025:** Updated version requires **no fire or explosion for 2 hours after thermal runaway starts**.

1. **How these system-level standards translate to their own technical requirements on material level?**
2. **How to guide enclosure design and material configuration to meet these requirements?**

Background: Thermal Runaway Testing for Battery Casings

UL 2596

- **Commonly used**
- **Biaxial load**
- Not tailored for all cell types
- Relies on availability of real cells and repeatability of the TR event

UL 2596 TaG

- **Commonly used**
- High repeatability by adjusting temperature and blast sequence
- Strong interdependency between flame and blasting parameters
- Standard approach with fixed parameters

Rocket test

- **Excellent screening method** suitable for single cell event with high impact velocities
- **No real cells needed**
- **Highly customizable**
- Does not consider prolonged exposure of specimens under flame
- Does not consider mechanical tensile loads

AZL MaStFire

Material strength test under fire

- Developed in **collaboration** with international consortium **incl. two German OEMS**
- **Excellent screening method** for top **venting pack layouts** for different cell chemistries
- **Customizable and repeatable**
- Consider **prolonged exposure** of specimens under flame and tensile load
- **Simultaneous flame and blasting** under **tensile** load
- **Limited to cold particle blasting**
- Cannot simulate the initial impulse blast
- Test method developed and available at AZL

AZL Torch and blast (1.0)

- **Developed in bilateral collaboration with an internation OEM**
- **Excellent screening method** for **alternative pack layouts** for different cell chemistries
- **Highly customizable and repeatable** for individual pack layout and cell chemistries
- Consider **prolonged exposure** of specimens under **flame and blasting**
- **Limited to cold particle blasting**
- Limited initial impulse
- Test method developed and available at AZL

AZL Torch and blast (2.0) ★

- ……
- ……
- **Integration of hot particle blasting (recommended by OEMs)**

Increasing need for optimization of battery systems requires more realistic and adaptable test protocols and capable testing systems

Background: Thermal Runaway Testing for Battery Casings

Previous Joint Partner Project On Fire Testing

2021 - 2022

Fire test setup

- Application relevant fire test set-up (Completed)
- Application relevant Instrumented test method developed
- **55+ different materials tested**
- **Report of 350+ slides**

Consortium

Audi, AsahiKASEI, Ascend Performance Materials, BMW, carcoustics, Celanese, CLARIANT, DIC, faurecia, Formosa Plastics Corporation, Frenzelit, HUTCHINSON, lyondellbasell, MAGNA, MARELLI, Mitsui Chemicals, REHAU, Röchling, SCOTT BADER, SEKISUI, SOLVAY, TEIJIN, TORAY

+ anonymous

List of materials types tested:

- Aluminium
- Steel
- Thermoplastics:
  - SGF
  - LGF / LCF
  - Hybrid
  - UD
  - Fabrics
  - Sandwich

  PP, PA, PE, PC, PPS, PK, CPVC, PMMA and Various FR formulations
- Thermosets
  - SMCs
  - Mats
  - UD
  - Fabrics

  Polyester, Epoxy, Phenolic, VE, PU and Various FR formulations
- Protection layers
  - Mica
  - Intumescent coatings
  - Blankets
  - Board
  - Foam

Background: Thermal Runaway Testing for Battery Casings

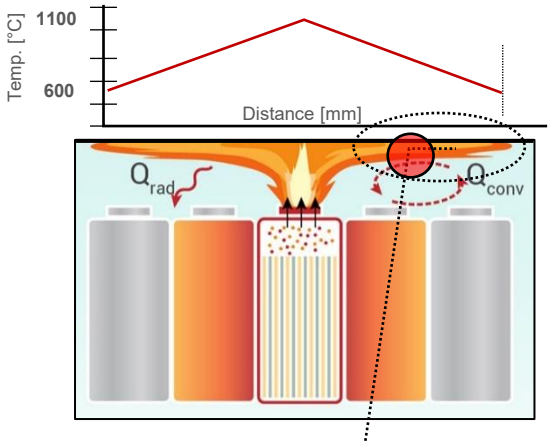
What's the need for tailor-made test profiles for material screening?

Cell chemistries and formats

- Cylindrical
- Prismatic
- Pouch
- Blade

NMC, LFP, NCA etc..

Typical fire behaviours in standard cells



Critical location
Adjacent material is pre-exposed to the flame between 500 to 900 °C before taking the particle blast (still within the 5 min escape time)

Ideal testing stages:

1. Pre-flame exposure
   - Short duration
   - High temperature
2. Particle blasting
   - Short duration
   - Ideally high temperature
   - High pressure blast
3. Post-flame exposure
   - Long duration
   - Lower temperatures

≥ 5 min

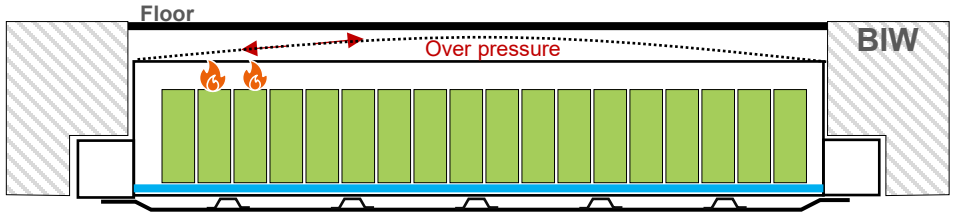
Fire behaviour and blast intensities might vary according to the cell chemistries and formats, but the exposure of protection materials remains more or less silimar

Background: Thermal Runaway Testing for Battery Casings

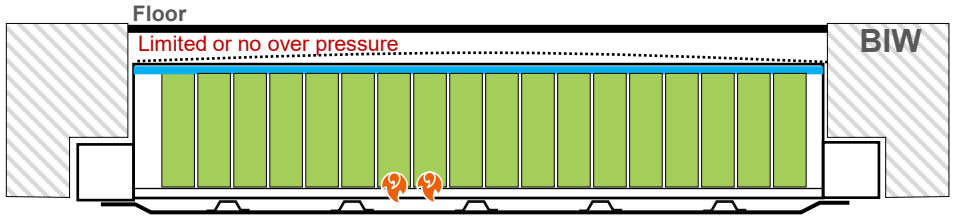
What's the need for tailor-made test profiles for material screening?

Pack layout and vent direction

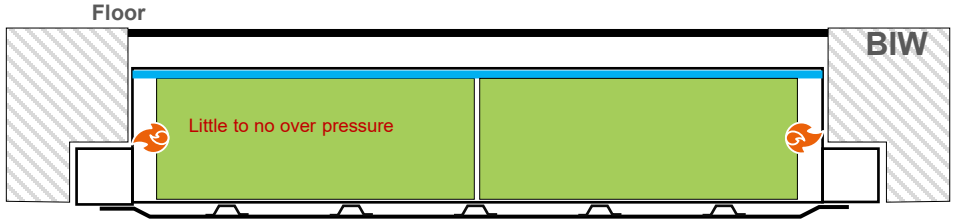
Cross section view



Top venting



Bottom venting

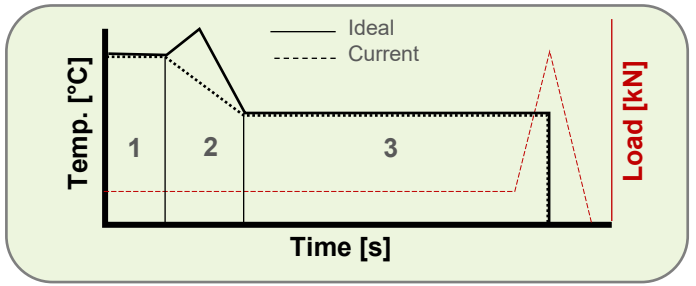


Side venting

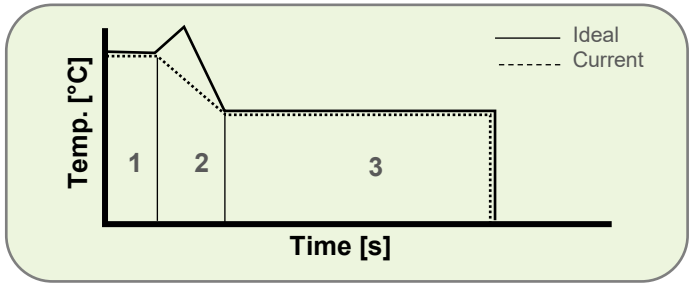
Load and boundary conditions

Valid for cylindrical, prismatic and pouch cells with varying flame and blast intensities

- Overpressure significant: 0.5 to 1 bar (incl. safety factor)
- Tensile or biaxial loading is relevant
- Pre-exposure of protection material to the flame
- Blast impact occurs once per location



- Overpressure is not significant due to venting location and lid is reinforced with cooling plates
- Pre-exposure of protection material to the flame
- Blast impact occurs once per location



- Overpressure is not significant due to venting location
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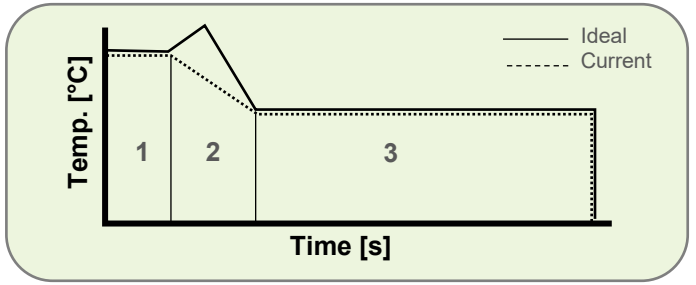


Example test profiles

Background: Thermal Runaway Testing for Battery Casings

AZL ongoing collaboration with OEMs to address diverse scenarios

Development of additional Test Method (Torch and blast)

Expanding Testing Capabilities:

- AZL is enhancing its battery pack protection testing methods to accommodate evolving battery technologies and safety needs.

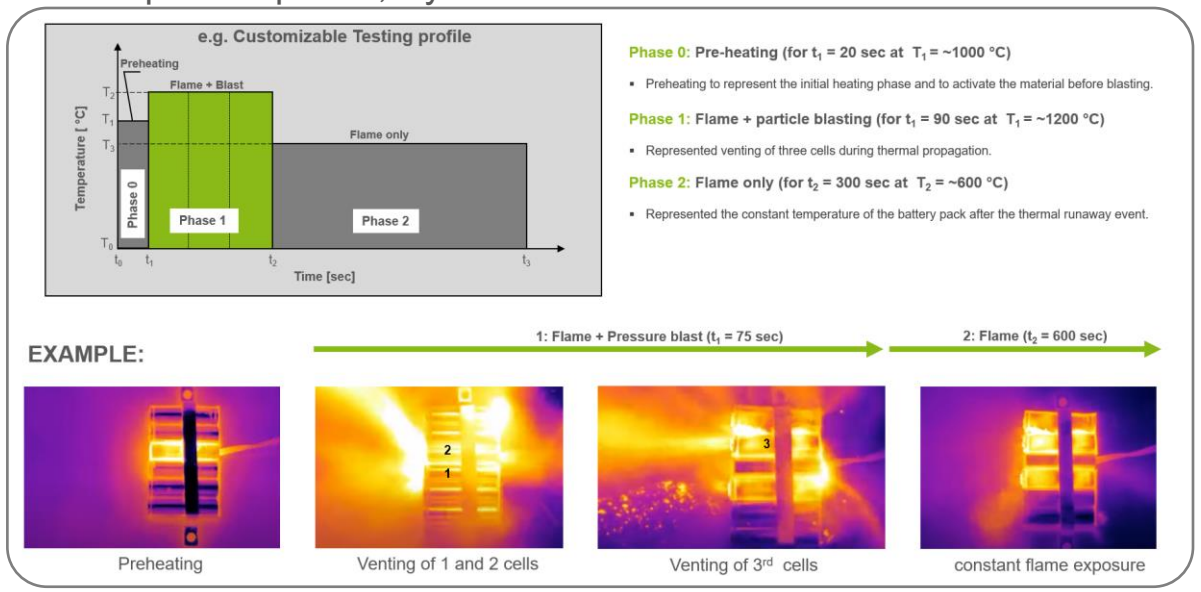
New Test Development:

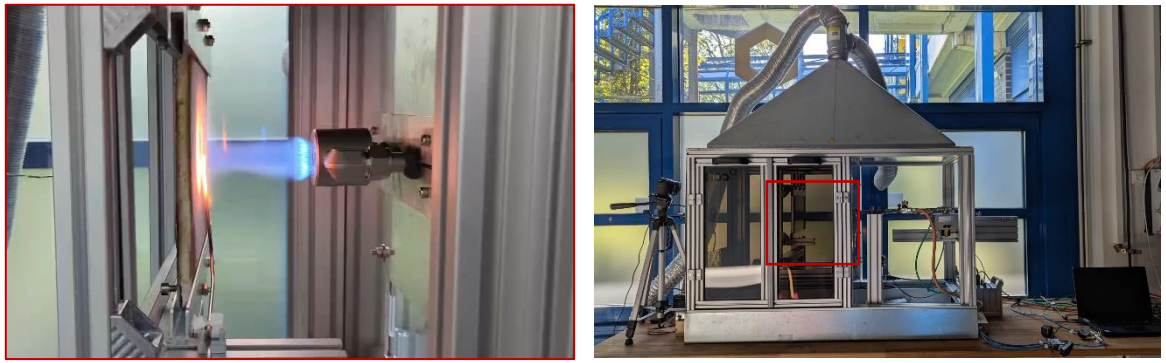
- AZL, in collaboration with a major **international OEM**, has **developed a first version of a high-temperature and high-intensity particle blast** test to simulate various thermal runaway behaviours.

Customization and Real-World Relevance:

- The new test is highly customizable and based on real-world experiments and data, ensuring its relevance as cell chemistries and battery pack designs evolve.

Example test profile, Cylindrical cells:

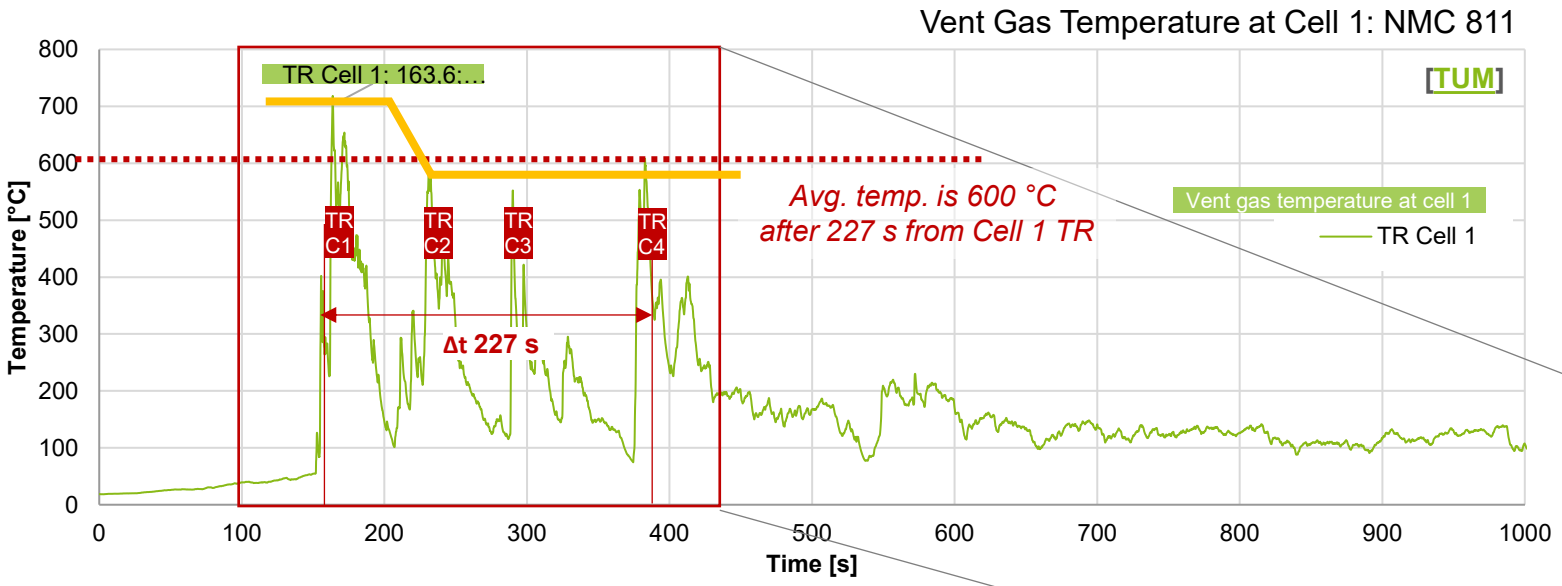


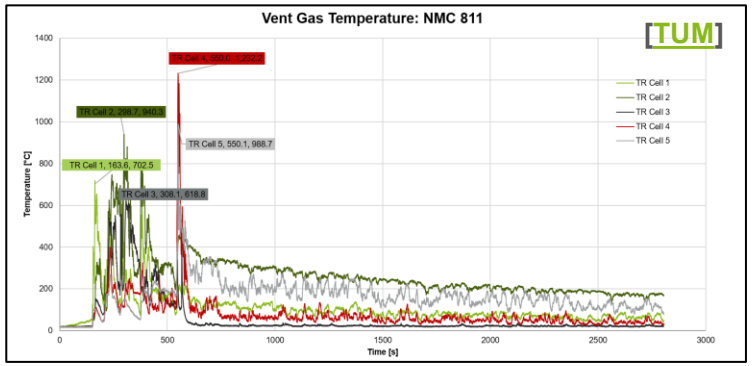


High intensity burner with integrated particle blasting developed in collaboration with an OEM

Background: Thermal Runaway Testing for Battery Casings

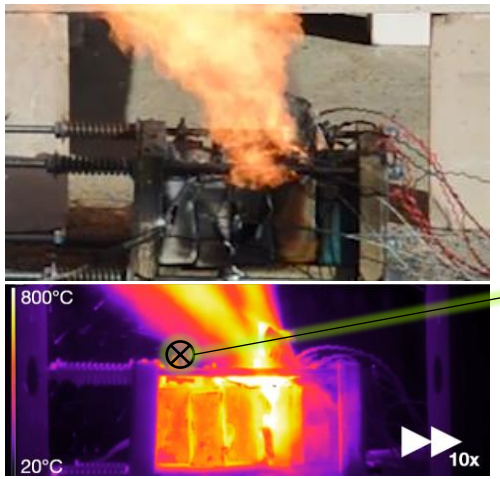
How to implement a tailored test profile from literature





Vent gas temperature for all 5 cells

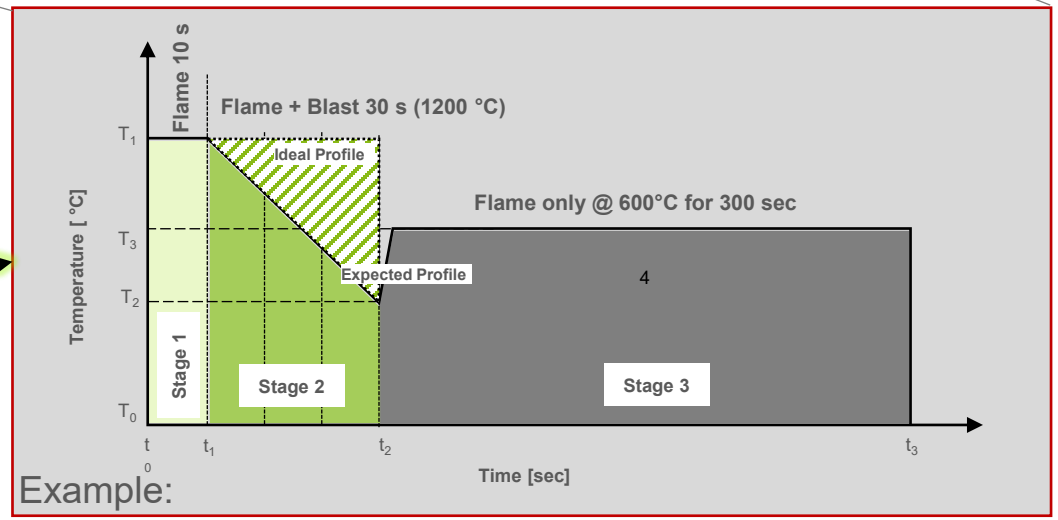
Example from literature experiment:



Screen shot @ t = 227 s

[TUM]

Extended test profile: Module Level

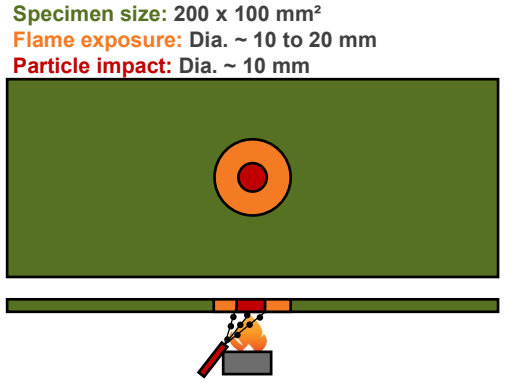


Background: Thermal Runaway Testing for Battery Casings

Example testing results simulating single cell TR event

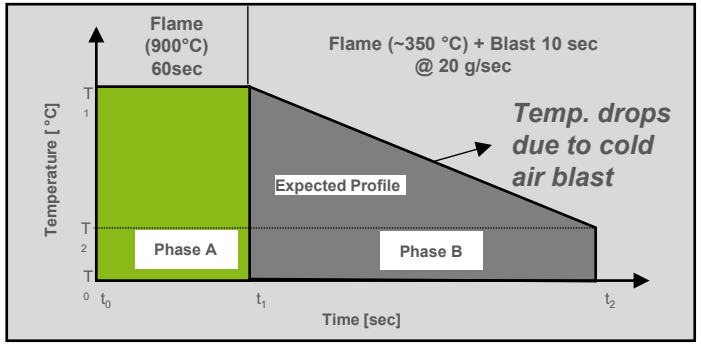
High Intensity Flame and **Par**ticle **Blast**ing Test (AZL 23-244: **HiParBlast**^{SiF})

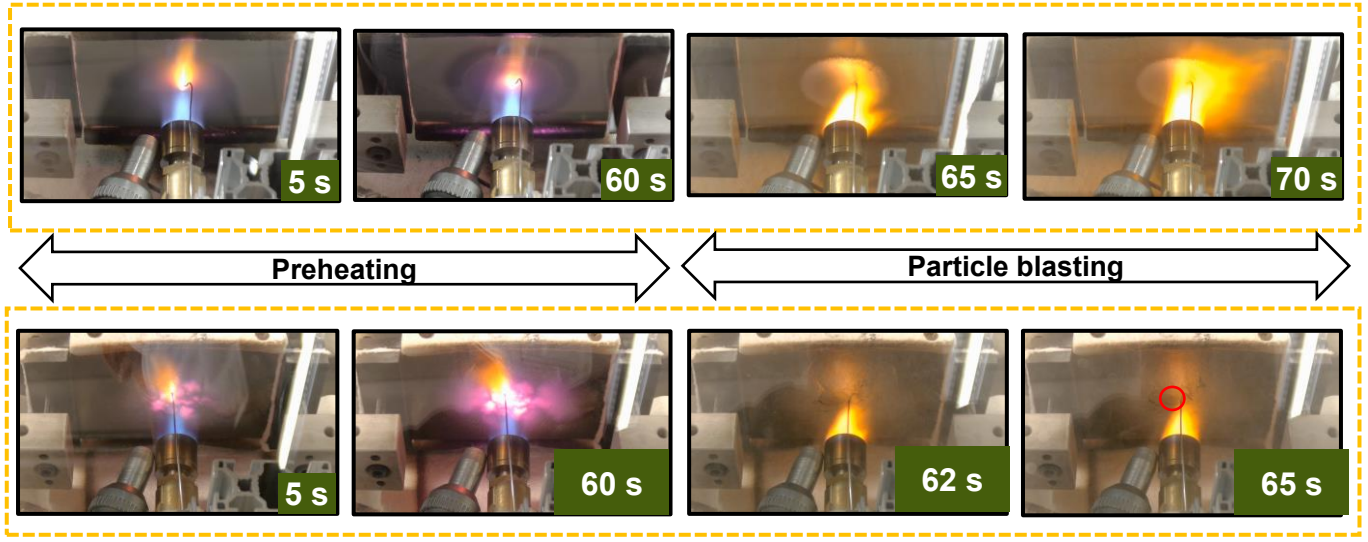
- Heating source: 4 kW **Si**ngle point **F**lame (SiF) at the center of the specimen
- "The test profile is customizable to reproduce the damage equivalent to various cell chemistries."
- Temperatures and durations
  - Up to 1350 °C for 10 to 600 sec
- Particle blasting mass flow and duration
  - Up to 20 g/sec for 5 to 60 sec
- *Example test profile for LFP: 60 sec of 900 °C flame exposure followed by 10 sec of particle blasting with 20 g/sec*

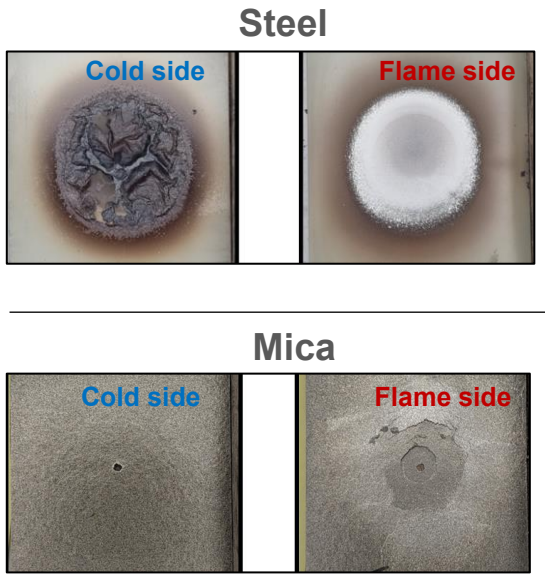


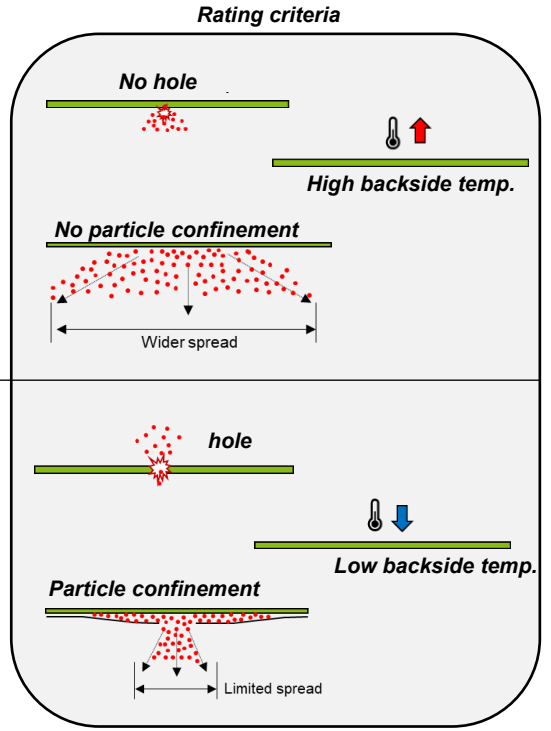
Cold particle blasting (20 to 30 °C)

Example:





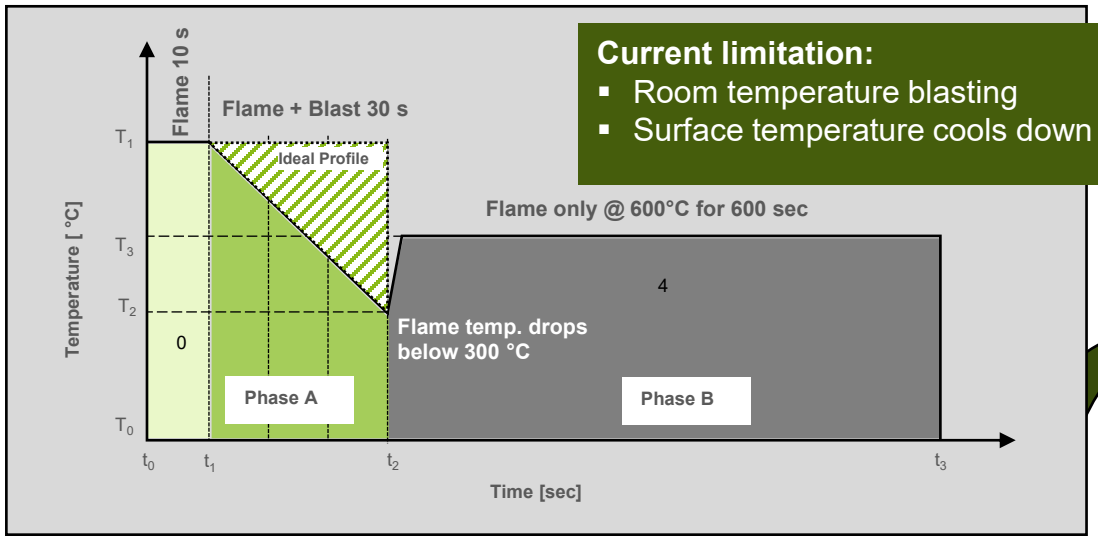




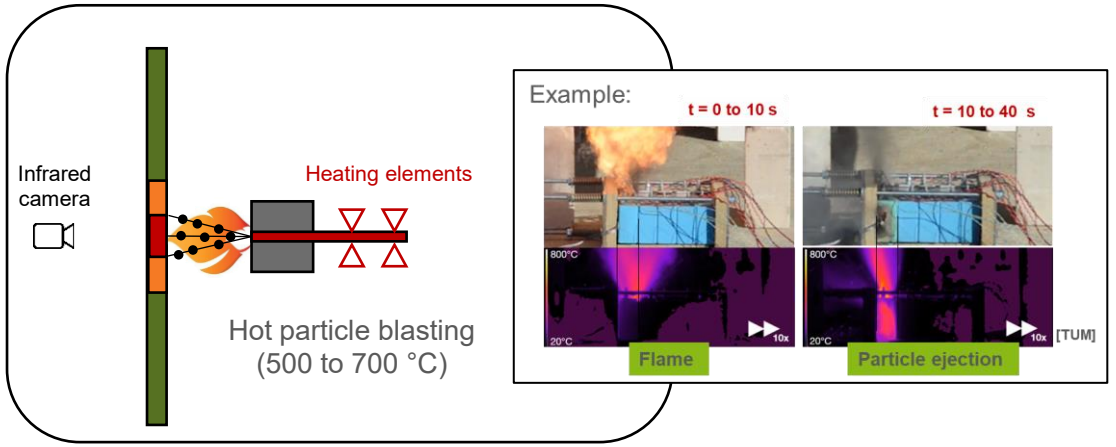
Joint Partner Project: Thermal Runaway Testing for Battery Casings

What do we want to achieve in this project

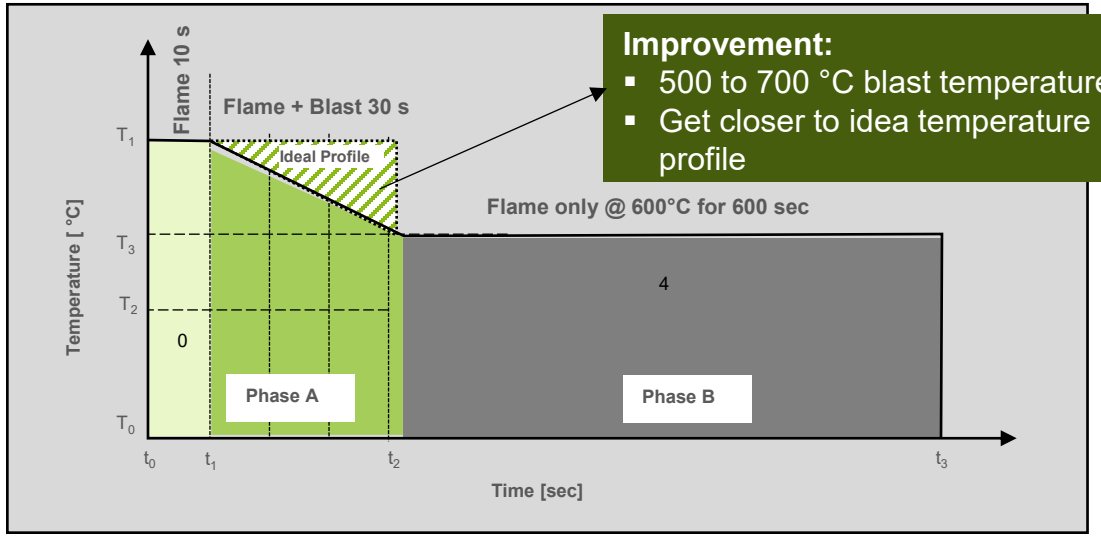
Example test profile: Module Level



Current limitation:
- Room temperature blasting
- Surface temperature cools down

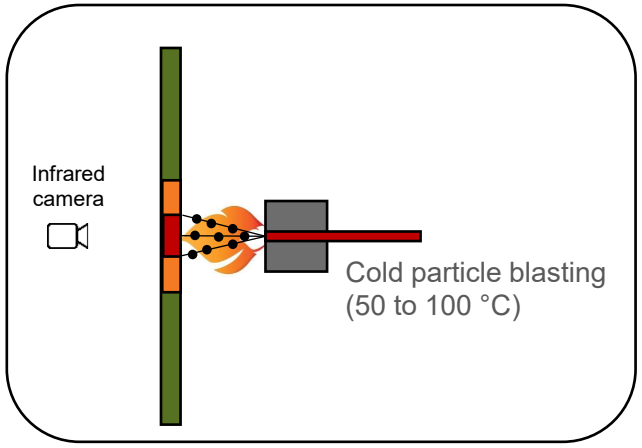


And what we propose to achieve in this project



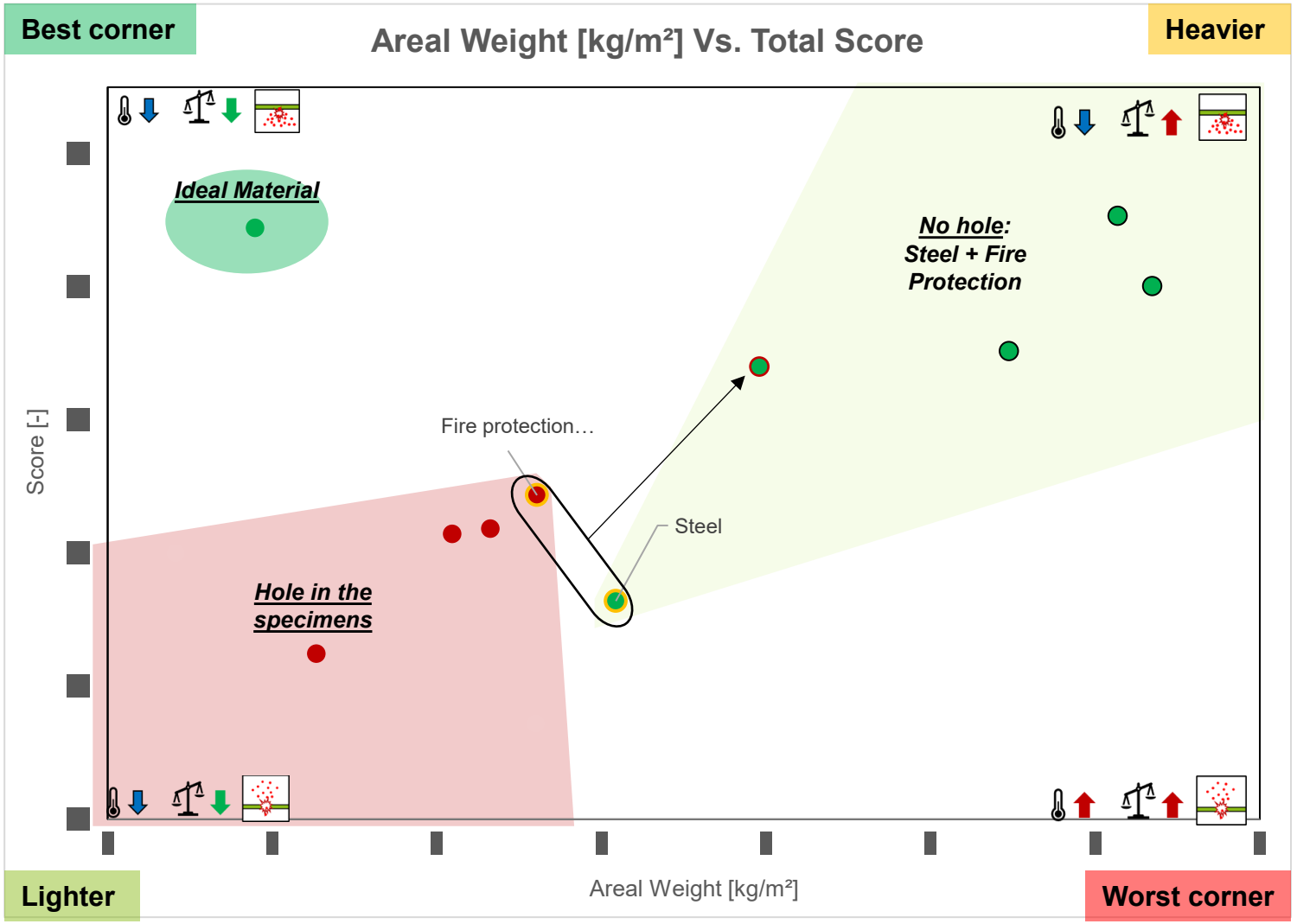
Improvement:
- 500 to 700 °C blast temperature
- Get closer to idea temperature profile

What we can do today



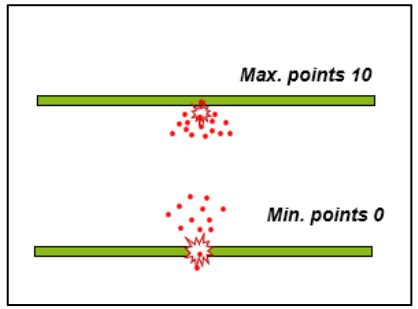
Joint Partner Project: Thermal Runaway Testing for Battery Casings

Application-specific challenges to rate material compatibility: Example

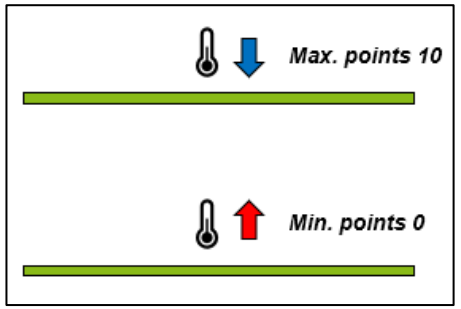


Comparative Analysis: Application-Specific Challenges and cost competitiveness

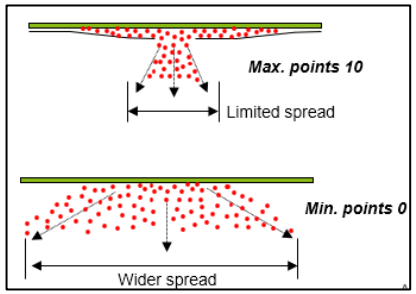
Incorporate cost and weight considerations for a comprehensive understanding in selecting the most suitable materials.



No hole Formation



Backside temperature



Confinement of particles

Joint Partner Project: Thermal Runaway Testing for Battery Casings

Project Objectives

Objectives:

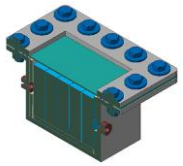
- Development and implementation of improved systems with high-gradient heating (flame temperature) and hot particle blasting without consider overpressure load
- Deriving application and cell chemistry specific testing protocols/profiles
- Evaluate candidate materials at the plaque or coupon level using these test protocols and reduce the resources and time required for prototyping and system-level testing.

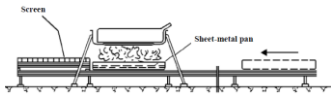
Results:

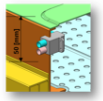
- Development and construction of test bench
- Tailored test profiles for relevant cell chemistries e.g. LFP or NMC cathode.
- Standard test profiles enabling screening of various materials for fire safe application in a battery casing.
- Comparison of relative performance of various materials and/or protection layers against tailored test profiles.
- Option to provide your materials for benchmarking
- Guidance to minimum material needs to survive battery fire testing according cell chemistry

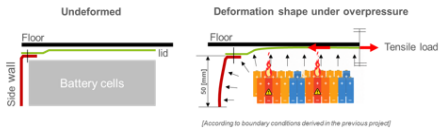
Joint Partner Project: Thermal Runaway Testing for Battery Casings

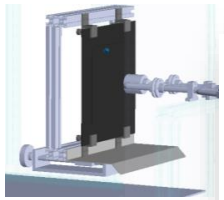
Work Packages

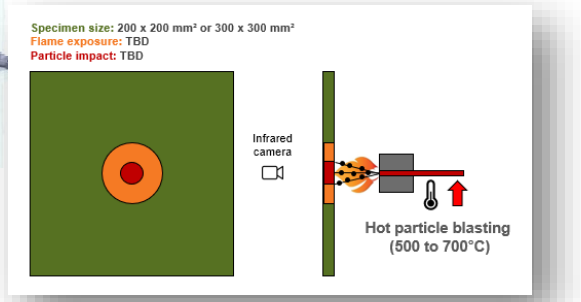


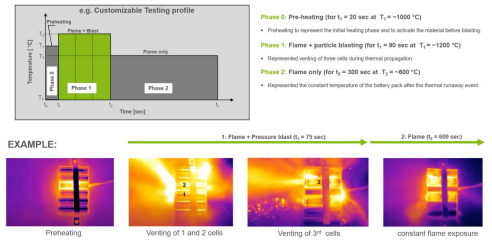












WP1
Analysis of state of the art

- Overview of existing test methods and benchmarking.
- Screening of regulation and interpretation on material level.
- Comprehensive Walkthrough for Test Bench Construction.
- Analysis of knowledge regarding testing of materials for structural and non-structural components of battery casings.

WP2
Development and implementation of improved systems for high-gradient heating and hot particle blasting

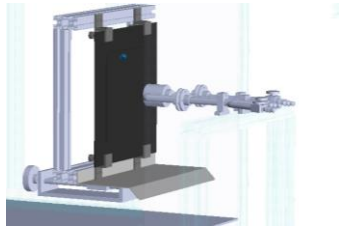
- Design and realization of test device.
- Implementation and integration of hot particle blasting system.
- Calibrations for different flame profiles and blasting intensities.
- Collection of test materials. Participants can provide materials for benchmarking.

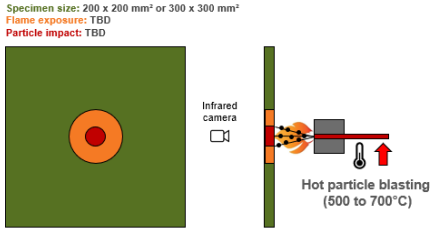
WP3
Implementation of relevant test profiles for different cell chemistries and benchmarking of test results

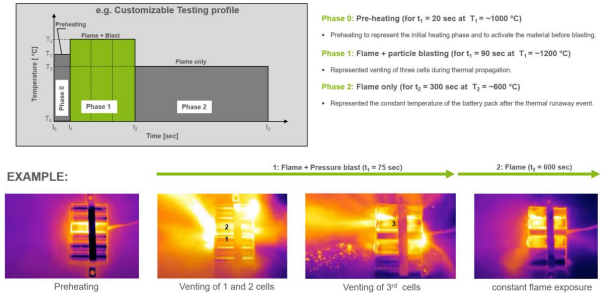
- Deriving application and cell chemistry specific testing profiles e.g. LFP, NMC.
- Test supplied material/ protection layers.
- Application-specific challenges to rate material compatibility.
- One on one comparison of market trending protection solutions including weight and cost indications.
- Guidance to minimum material needs to survive battery fire testing according cell chemistry

Joint Partner Project: Thermal Runaway Testing for Battery Casings

Estimated Timeline



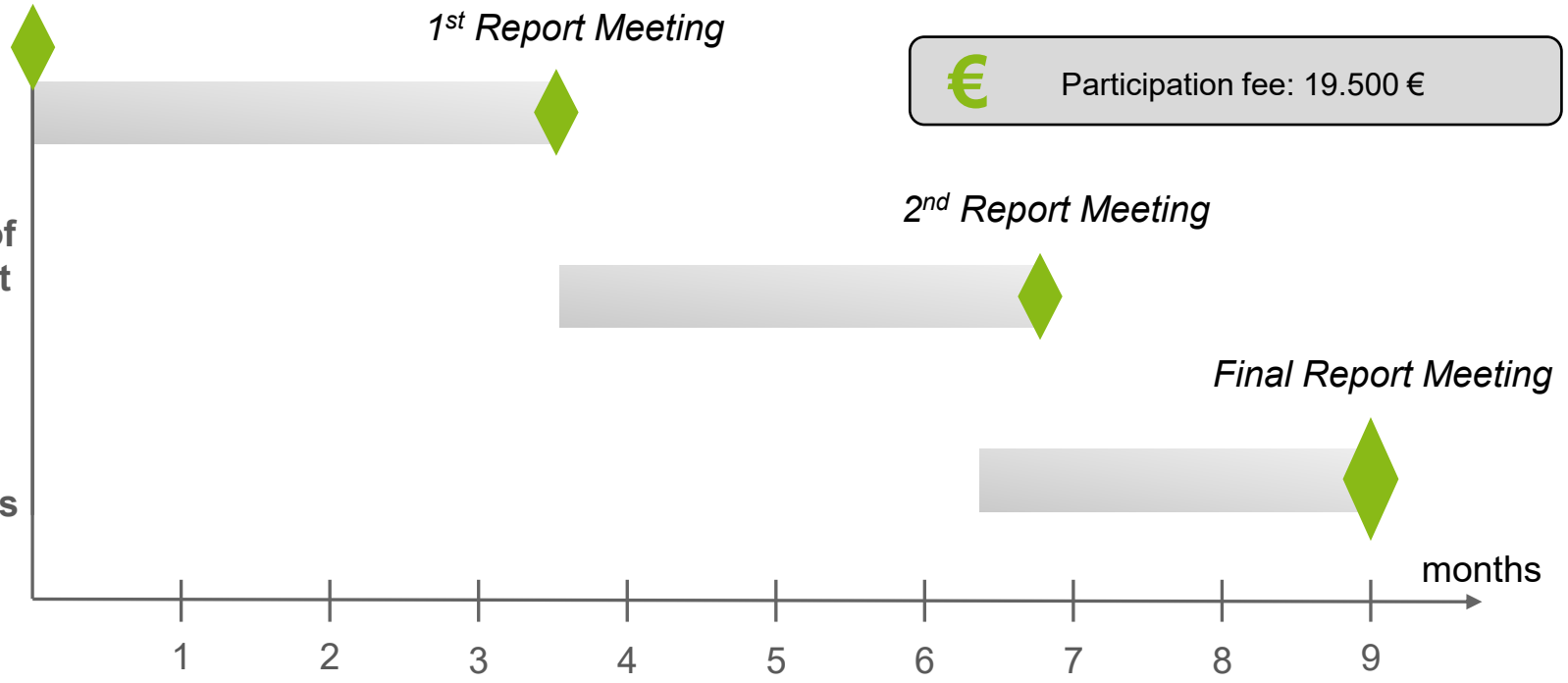




WP 1:
Analysis of state of the art

WP 2:
Development and implementation of improved systems for high-gradient heating and hot particle blasting

WP 3:
Implementation of relevant test profiles for different cell chemistries and benchmarking of test results



€ Participation fee: 19.500 €

Joint Technology Development through Cost-Sharing

Efficiently drive your development!

What it is

Within the AZL Joint Partner projects, international companies come together to improve their understanding of trend topics & their markets, to optimize technology and business development strategies and to develop approaches to solve future challenges.

How it works

Project proposal → Compilation of a project consortium → Kick-off with input from the consortium → Project work will be carried out by AZL → Validation of the results by the consortium → Direct access to all results

How you benefit

Joint Technology Development through Cost-Sharing

Previous Activities

Joint Partner Project
Trends & Design Factors for Hydrogen Pressure Vessles

Joint Partner Project
Thermal Propagation

Joint Partner Project
Rotor Sleeves for Electric Motors

Joint Partner Project
Emerging Battery Storage Technologies

Joint Partner Project
Propellers and Rotors

Joint Partner Project
Cost and CO2 Saving Lightweight Tailgate Concept Study

Joint Partner Project
Concept Study & Development of Cell-to-Pack Battery Casings

Joint Partner Project
Battery Casing Follow-Up: Bottom Impact Protection

Joint Partner Project
Battery Casing Follow-Up: Fire Protection

Joint Partner Project
Multi-Material Battery Casing

Joint Partner Project
Inductive Double Belt Press

Joint Partner Project
Ultra-Fast Manufacturing

Joint Market & Technology Study
New Potentials for Composite Technologies in Buildings & Infrastructure

Joint Market & Technology Study
Composites in the Furniture Industry

Joint Market & Technology Study
Potentials and Challenges of Thermoplastic Tapes for SME Injection Molders

Joint Market & Technology Study
Next Generation Mobility Solutions

Joint Market & Technology Study
Energy Storage Systems

Joint Market & Technology Study
High-Performance SMC

Joint Market & Technology Study
Bio-based Composites

Get more details on completed activities!

CONTACT US WITH YOUR REMARKS AND QUESTIONS

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Excellence in Lightweight Production




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