
# An efficient pathway to a safe battery in everyone’s garage

Dr. Bernhard Brunnsteiner

# Agenda

**Introduction**

Synergies between engineering, test systems and software development

**Thermal Propagation**

Target definition, state-of-the-art and future demand

**Main Challenges in development to ensure safe battery design**

Handling the hazard of single cell failure

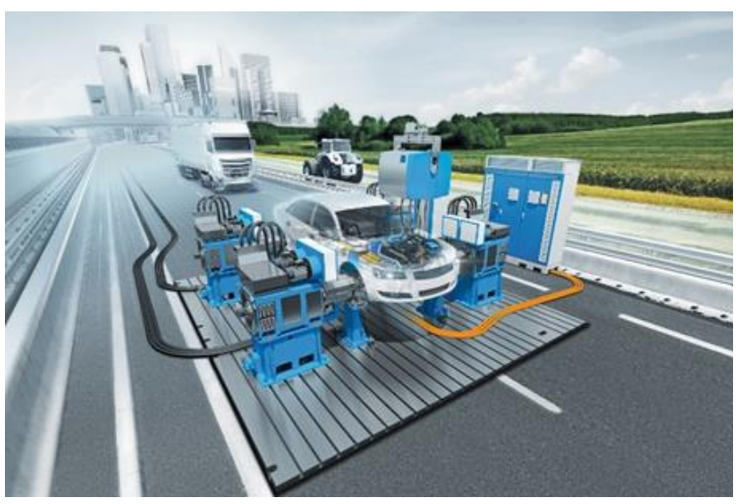
Considering various side effects and physical phenomena in the system

**Take Away & Conclusion**

# Three Disciplines Under One Roof

## ENGINEERING SERVICES

- Design and development services for all elements of ICE, HEV, BEV and FCEV powertrain systems
- System integration into vehicle, stationary or marine applications
- Supporting future technologies in areas such as ADAS and Autonomous Driving
- Technical and engineering centers around the globe



## INSTRUMENTATION AND TEST SYSTEMS

- Advanced and accurate simulation and testing solutions for every aspect of the powertrain development process
- Seamless integration of the latest simulation, automation and testing technologies
- Pushing key tasks to the start of development

## ADVANCED SIMULATION TECHNOLOGIES

- Indispensable tools for knowledge generation and decision making
- Simulation Software Solutions for all phases of the powertrain and vehicle development process
- High-definition insights into the behavior and interactions of components, systems and entire vehicles

# What is Thermal Propagation?

## Single Cell Failure


## Event Detection


## Fire outside Pack

# Thermal Propagation Targets & Requirements

## >5min

- Current legal requirement (GB 38031-2020 )

GB

NATIONAL STANDARD OF THE

PEOPLE'S REPUBLIC OF CHINA

ICS 43.080

T 47

**GB 38031-2020**

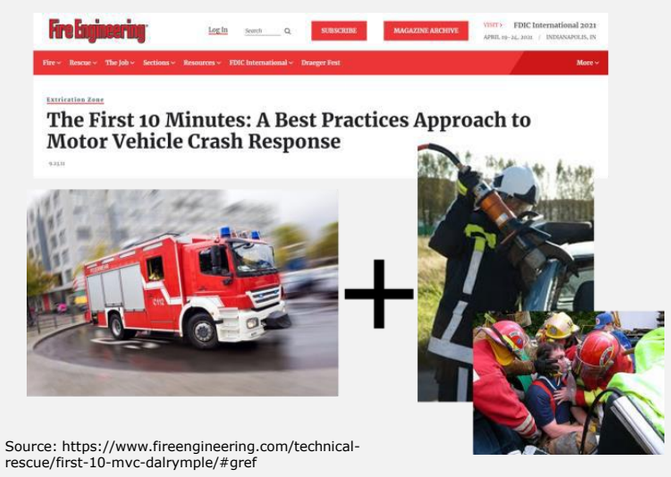
Replacing GB/T 31485-2015, GB/T 31467.3-2015

**Electric Vehicles Traction Battery Safety requirements**

电动汽车用动力蓄电池安全要求

## >15/30min

- considers even time demand for fire fighters arrival or escape time demand for injureds




Source: https://www.fireengineering.com/technical-rescue/first-10-mvc-dalrymple/#gref

## No Propagation

- Future requirement
- Ensures safety even for infrastructure and parking surrounding

→ safe for parking in garage

# No Propagation
# the only way to ensure safety in every circumstance

Source: https://www.nbcnews.com/business/autos/federal-regulators-warn-risks-firefighters-electrical-vehicle-fires-n1271084

Source: https://electrek.co/2020/10/12/hyundai-recall-77000-kona-electric-cars-risk-battery-fire-lg-chem/

# No Propagation
# the only way to ensure safety in every circumstance


No Propagation **means**:

no flames out of battery without time limit

# No Propagation
# the only way to ensure safety in every circumstance


No Propagation **requires**:

| | | | | |
|---|---|---|---|---|
| Right Chemistry | no gas ignition | no/slow cell2cell propagation | robust & stable design | heat sink |

no
gas ignition

no/slow
cell2cell
propagation

robust &
stable
design

***Challenges:***

Cell Thermal Runaway

Cell2Cell Propagation

Cover Deformation

Sealing, Tightness

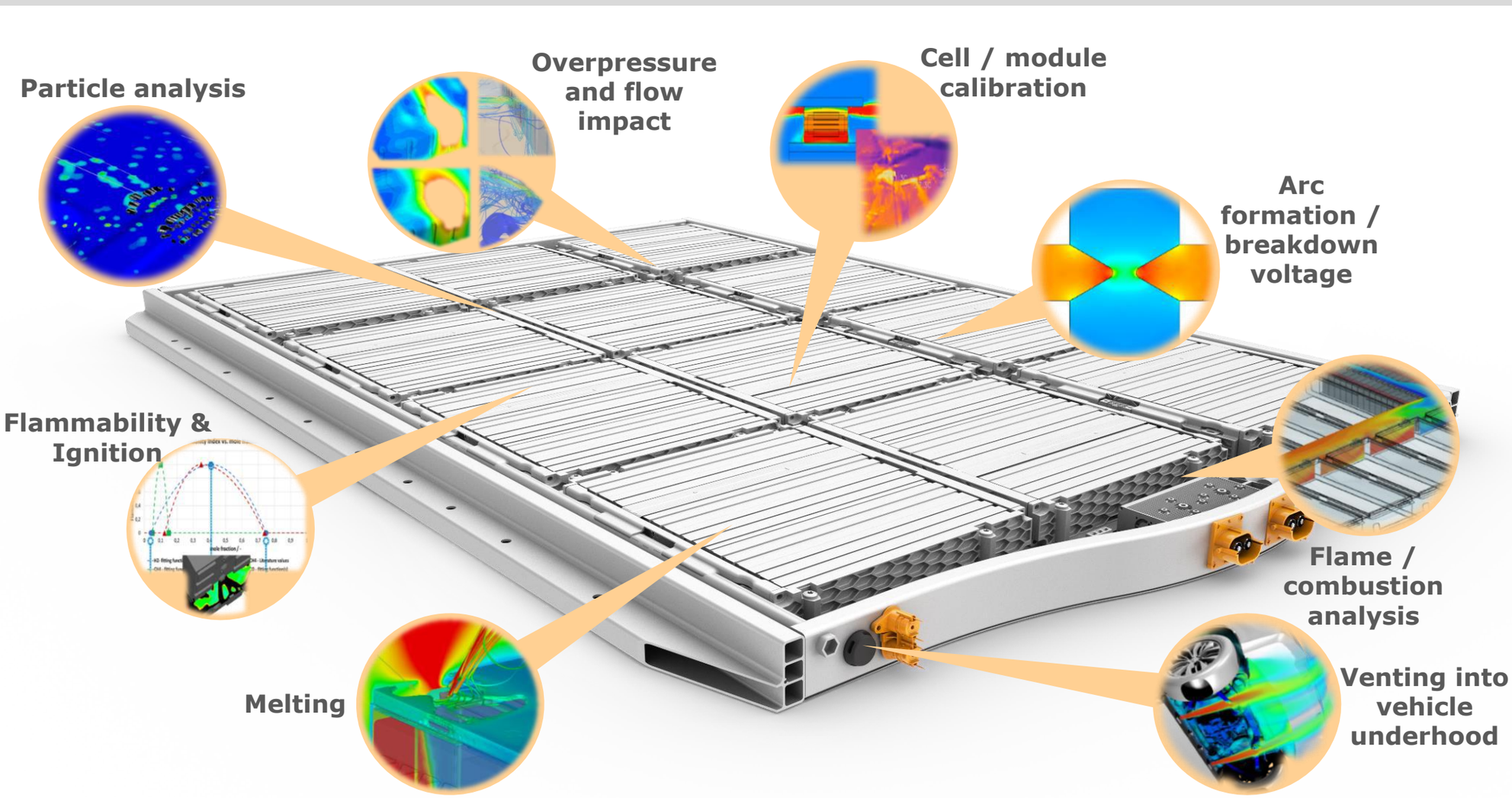
Venting device

Gas Ignition

Material melting

Particle Abrasion

Arcing & breakdown voltage



# Cell thermal runaway as driver of thermal Propagation modelling of fast heat release, gas & particle flow

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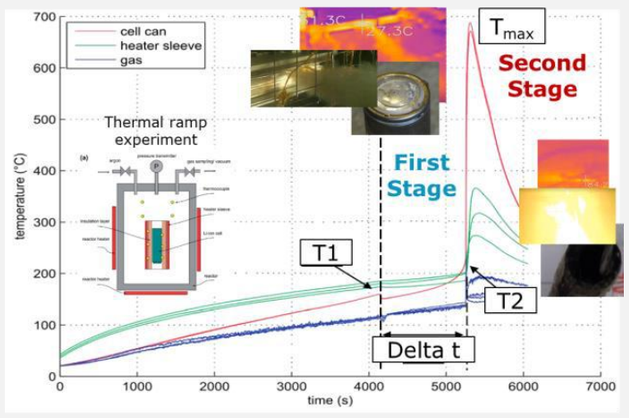
## Electro-chemical cell abuse behavior

exothermic reactions that is accelerated by temperature rise
2 phases:

- 1st: slow temperature rise
- 2nd: very fast Z& severe




- **T1** = first onset T
- **T2** = second onset T
- **T max** = maximum T
- **Delta t** = time between T1 & T2

## Cell Characterization Testing

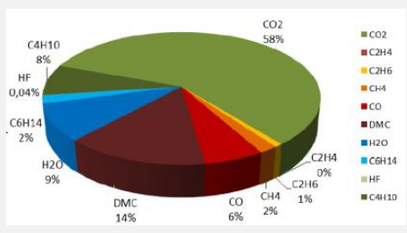


**Standard test program**

- 3-4 tests
- Thermal triggered event

**Measured quantities**

- Heat release
- Gas temperature & pressure
- Gas volume & composition



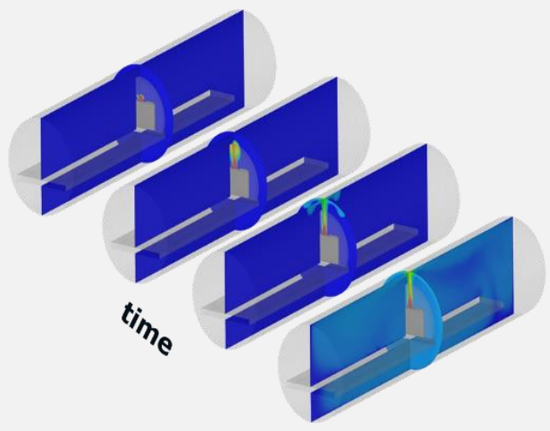


## Gas & Heat Release Model

**Modeling of**

- Gas release
- Temperature dependent heat release
- Gas composition after venting event
- Cell expansion
- Particle flow

**Model validation**



# cell venting, heat release & cell expansion during thermal Runaway is driving the cell-to-cell propagation time

***Challenges:***

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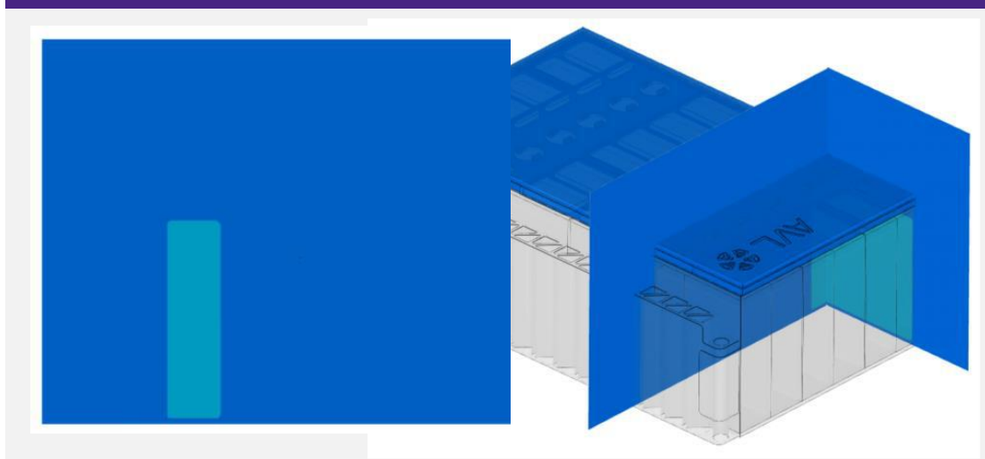
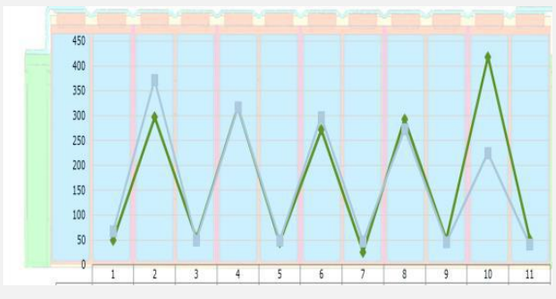
## coupled consideration of cell expansion and heat transfer

Compression pads and insulation layers needs to be optimized for meeting swelling and propagation requirments

## Delay/avoid cell-to-cell propagation






Cell2cell propagation time must be delayed so that energy release can be handled by the housing

# Cover Deformation
# overpressure inside pack due to venting gas release by cell

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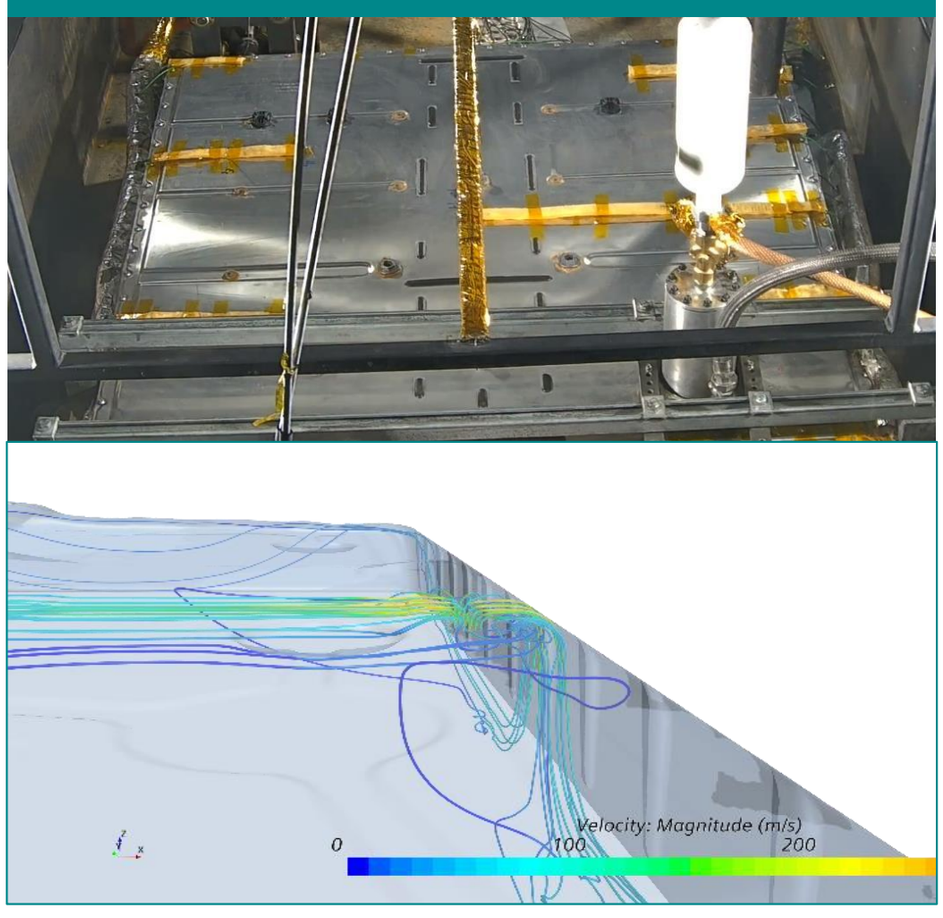
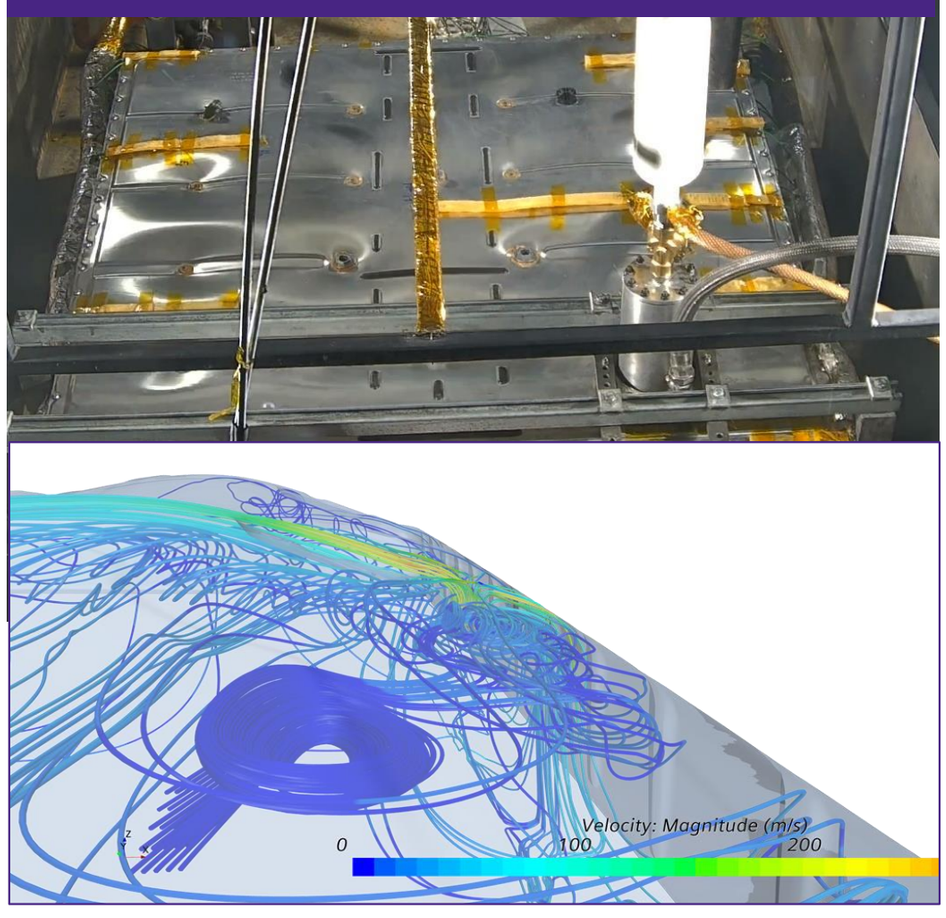
## undeformed




## deformed



# Sealing & tightness of pack must grantee no uncontrolled gas release

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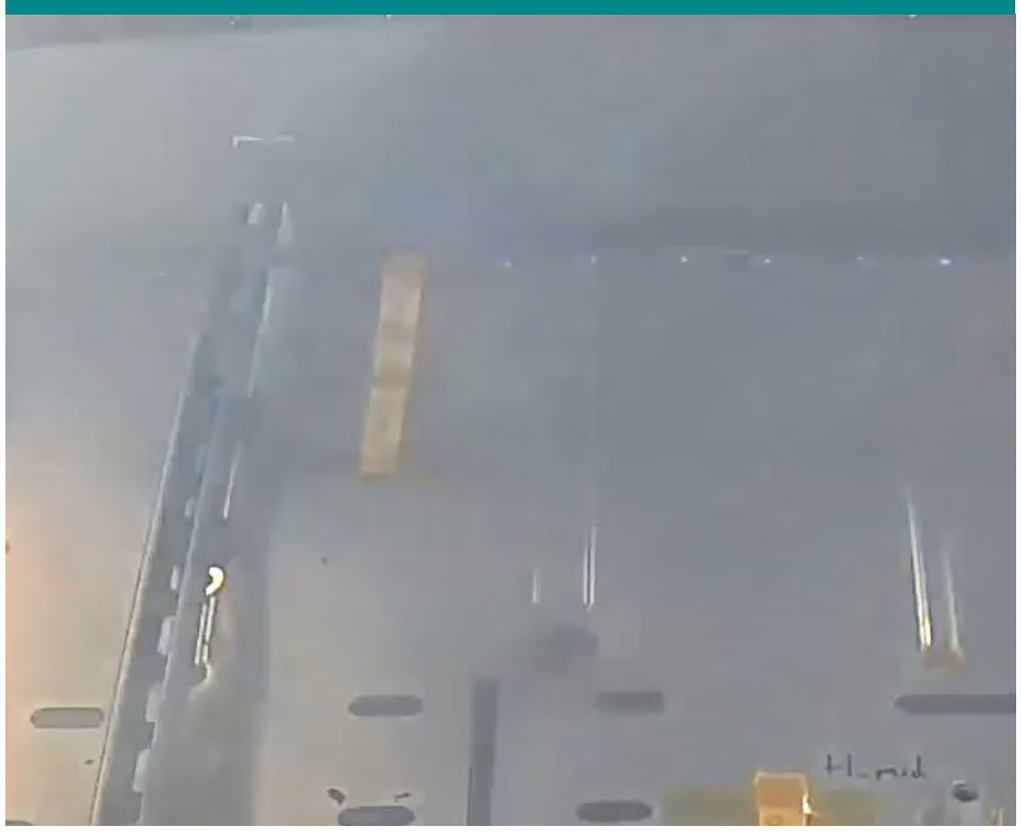
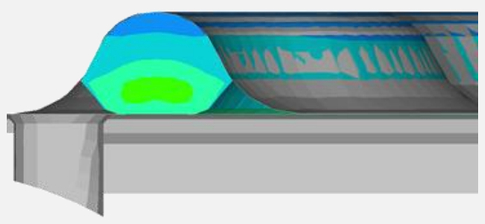
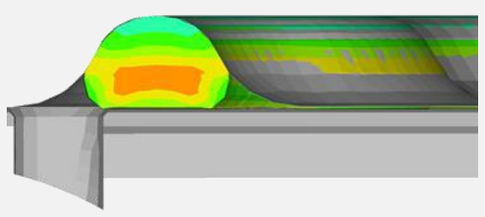
## Leakage in sealing line releases gas which ignites

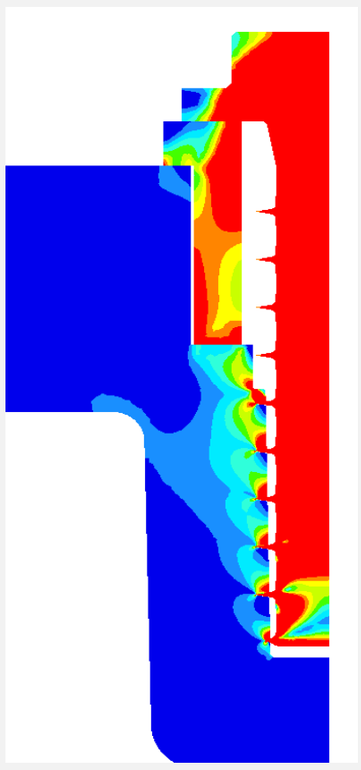


## Virtual assessment of sealing function and bolt connections

Consideration of temperature gradients & cover deformation due to venting gas accumulation for a robust and tight mechanical design







# Venting device

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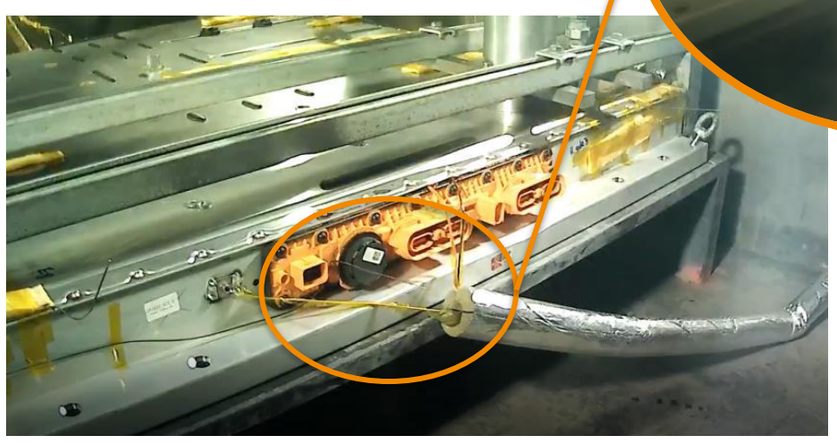
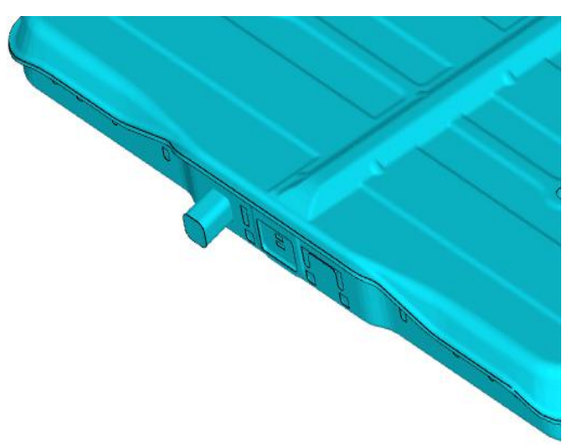


Simulation of venting gas flow and prediction of gas ignition outside venting device



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# Gas Ignition dependent from temperature and gas concentration → local & time dependent

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**Gas Ignition**

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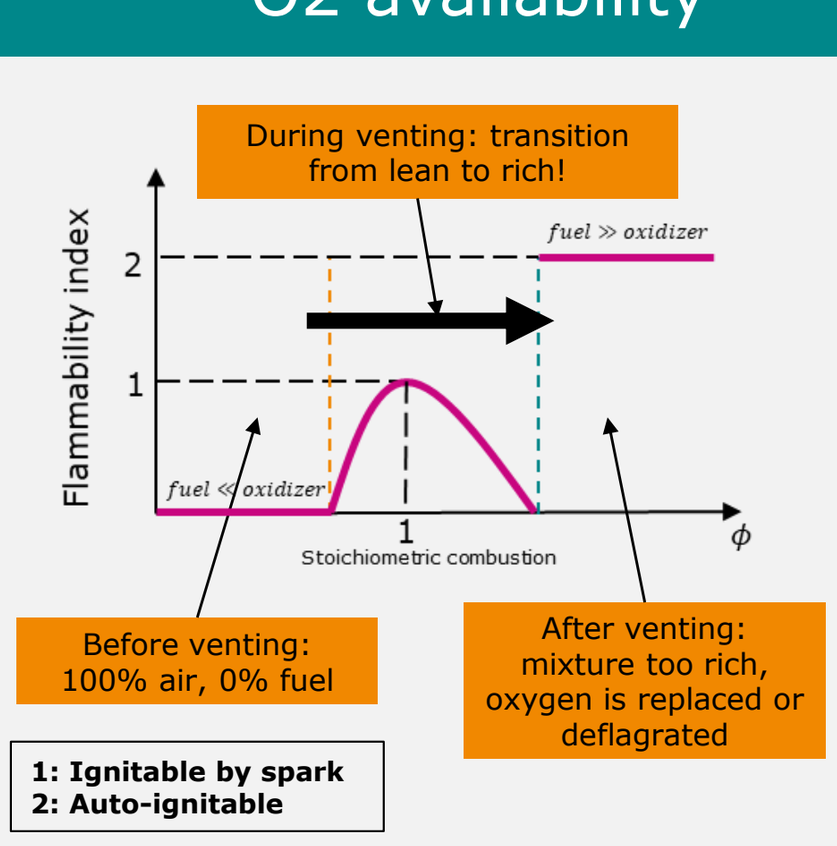
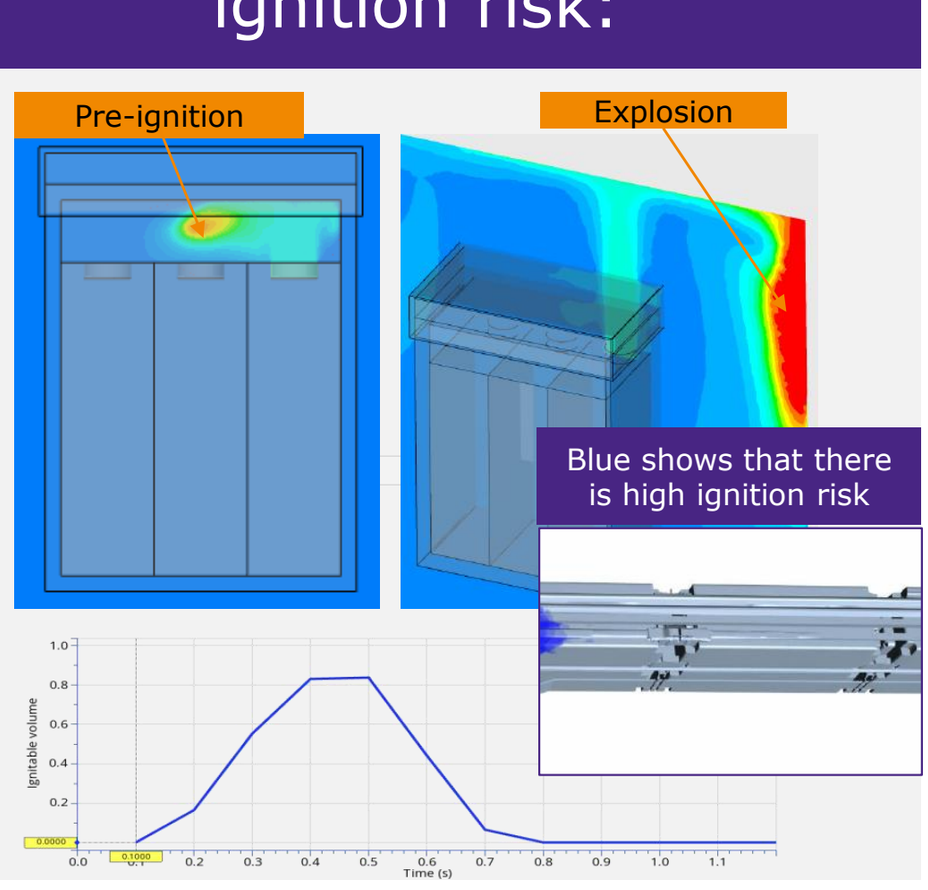
## Gas ignition dependent from O2 availability




## Transient prediction of ignition risk:



# Material Melting
# impact on flow field, insulation function & risk of ignition

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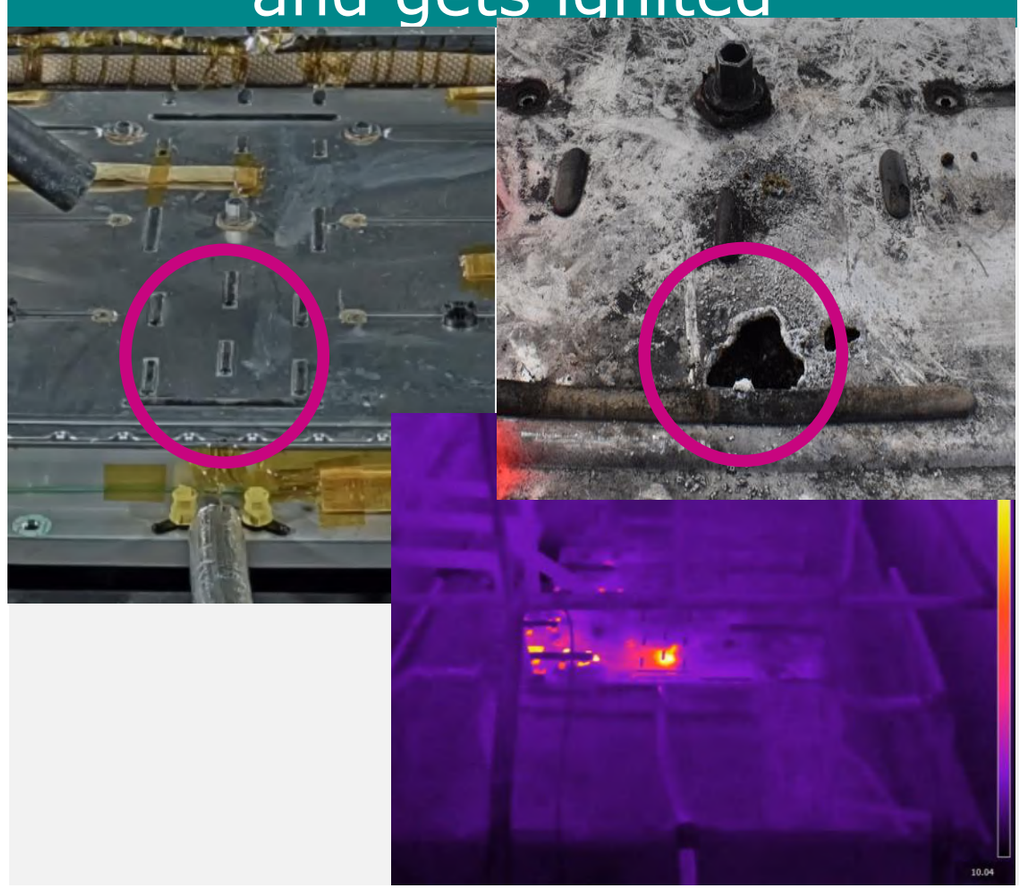
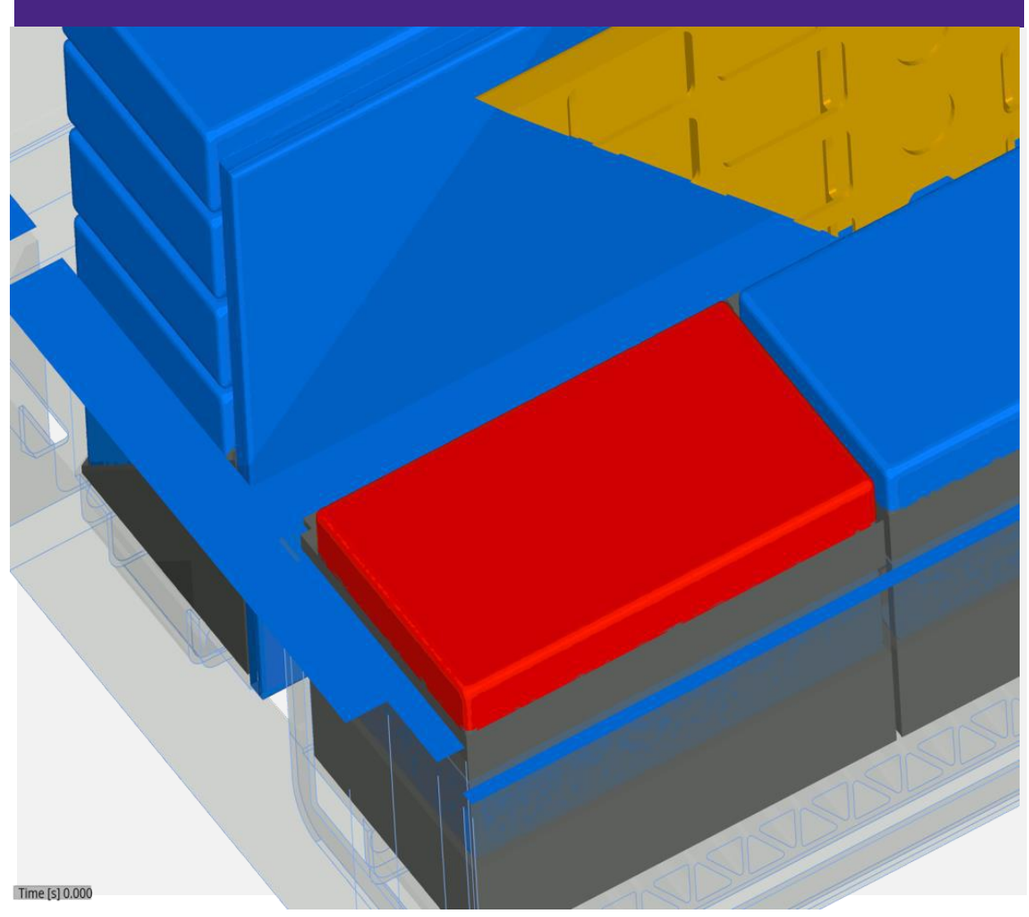
## Cover melts, gas releases and gets ignited



## material melting



# Particle simulation
# ejected particles are abrasive & electrically conductive

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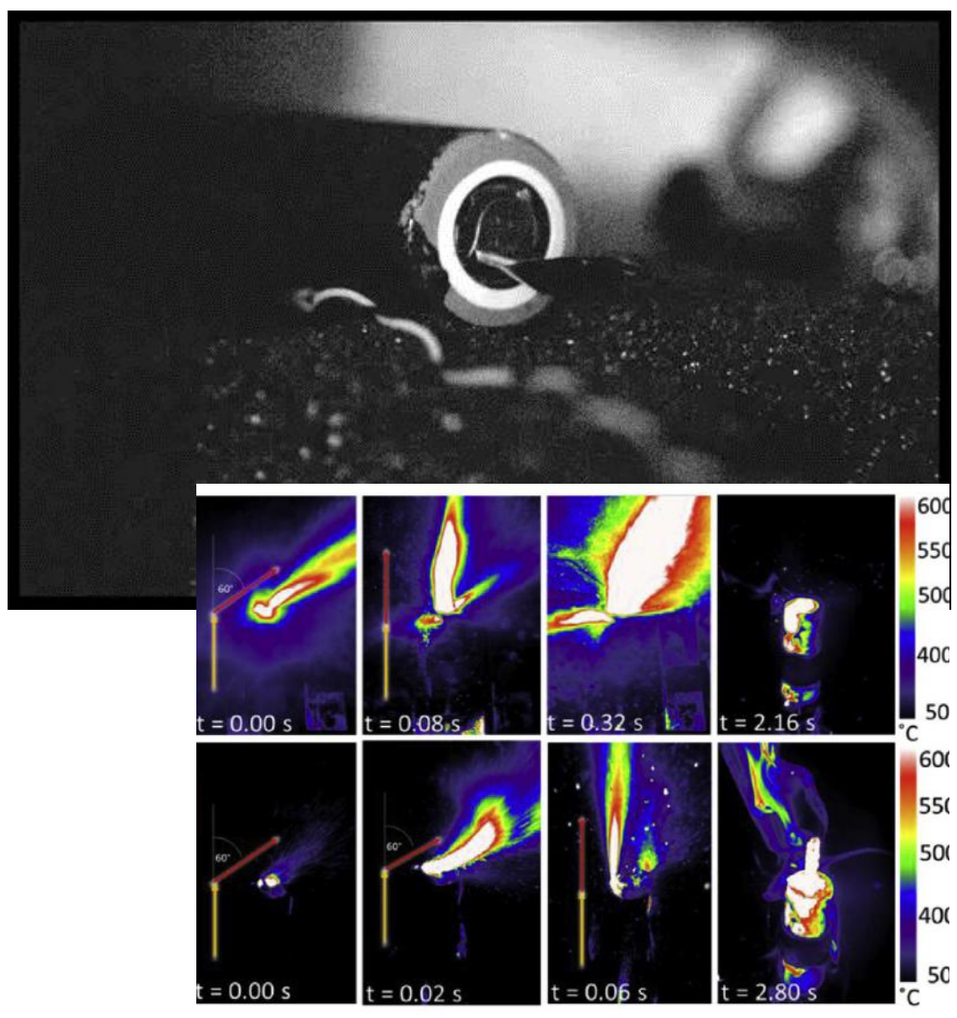
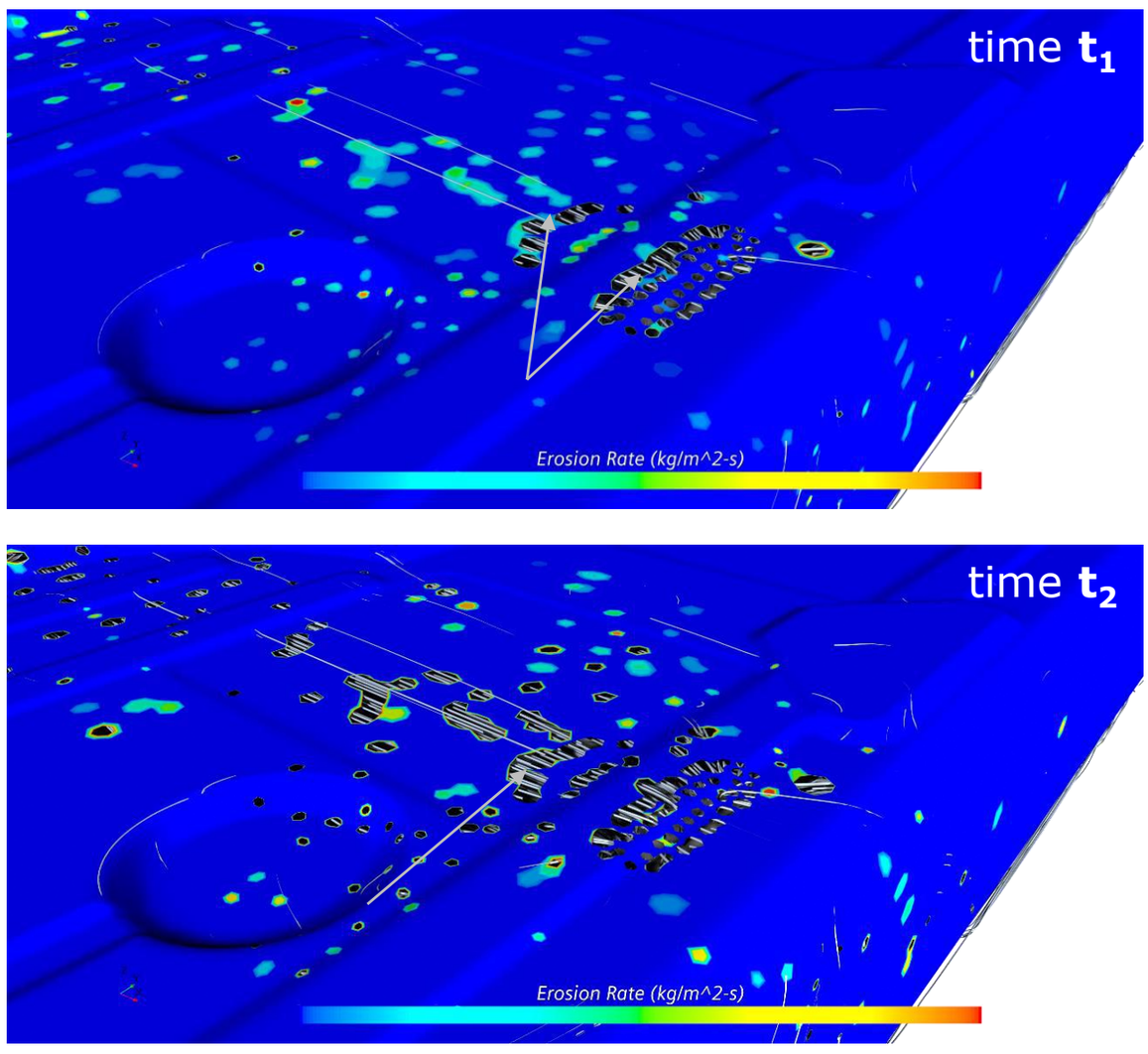



Source NREL: Part of global MIT R&D cooperation



# Sparks & electrical arcs as main failure mode

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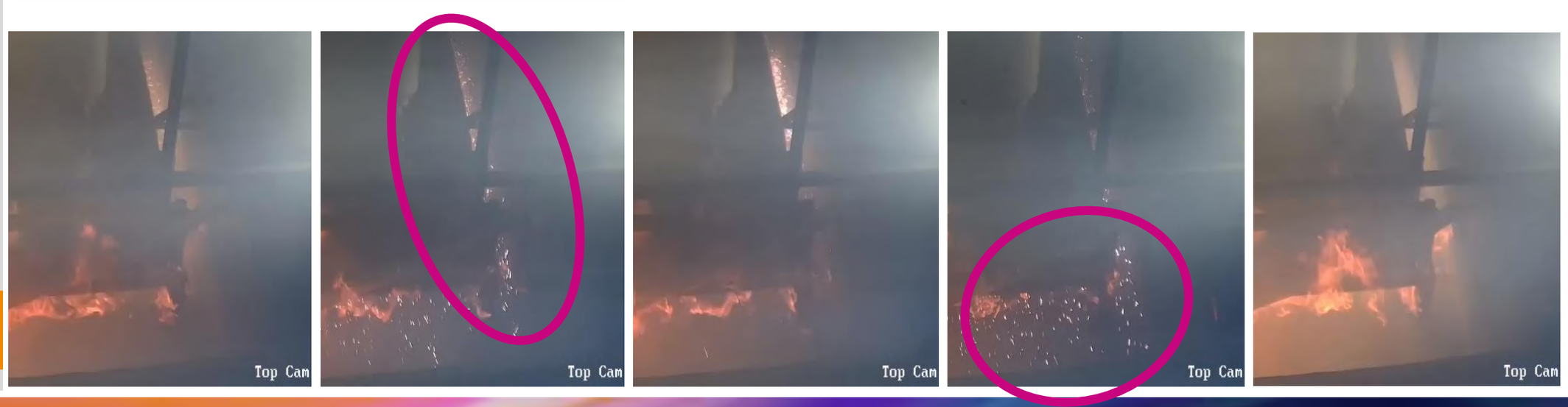
Arcing & breakdown voltage

Ejection of conductive & incandescent particles by the cell

Sparking and arcing by HV and metal parts

# Electrical arc as failure mode for housing damage & ignition

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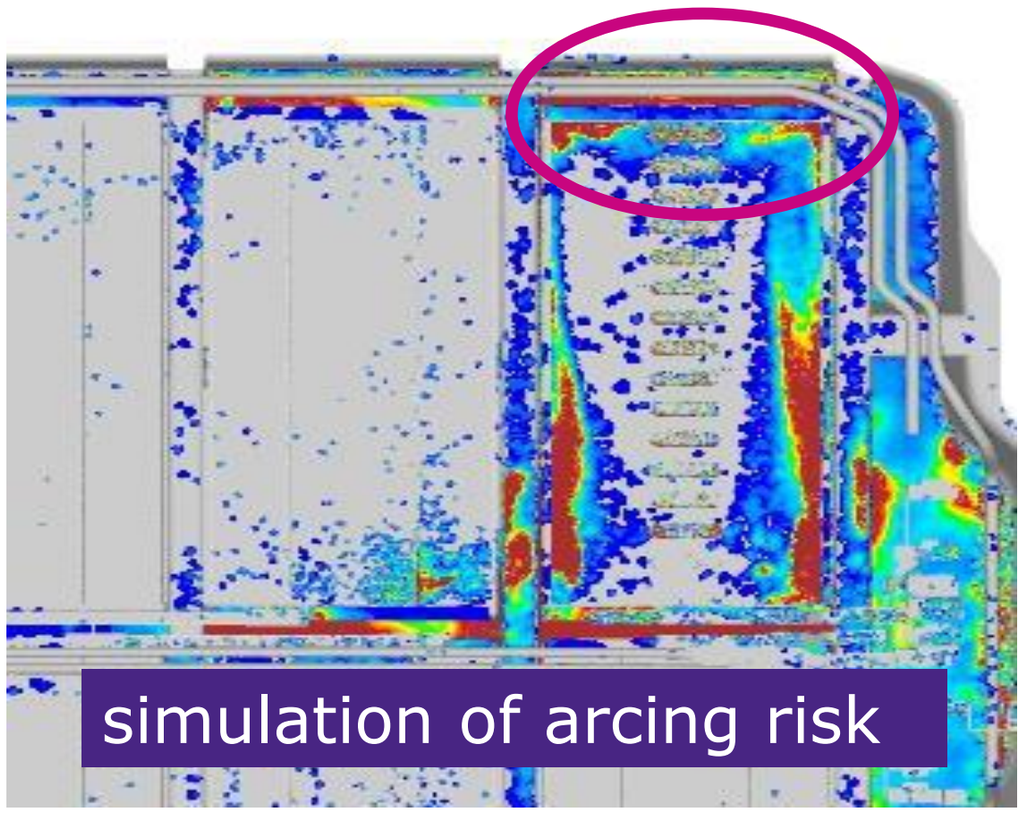
**Arcing & breakdown voltage**

## Electrical arc melts hole in cover & ignites gas

## Red zones are areas with high risk of electrical arcing



simulation of arcing risk

# Conclusion
# Take Away

## Take Away

"No Propagation" requires **new concept approach**

- Right chemistry
- No gas ignition
- Slow cell2cell propagation
- Robust & stable design
- Heat sink

Safe design principles like separating venting flow path & HV system or proper venting release are required

## Methodology

Coupling of test analysis with simulation results is the key for **gaining deep understating** and knowhow

**Full virtual development** approach is developed

- Concept definition & decision making in design process
- Design verification

**Method applied** in **concept** studies, **SOP** developments & **trouble shootings** as well

## Conclusion

Beside electro-chemical cell reactions, physical phenomena like ignition, combustion, melting, abrasion or arcing are driving the propagation behavior

Robust design concepts are required for safe battery design

New and better design solutions are required and must be developed by material suppliers, Tiers and OEMs

Thank you

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