

A Review of Battery Safety for Electric Vehicles and their Impact on Developing Materials

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3M at a Glance



- Sales in nearly every country
- \$32.8 billion in sales
- Four business groups
- 93,000 3Mers globally
- 117,000 patents
- 100+ straight years of dividends
- One of 30 companies on the Dow Jones Industrial Index



3M Automotive Electrification

Solutions to enable Future Mobility

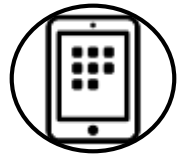
A Proven Track Record in Automotive

Bringing robust Product Development, global Scale, and reliable Solutions for every Phase of the Vehicle Design and Assembly Process to the World of Automotive Electrification.

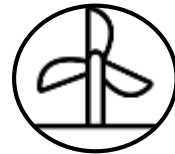
Leveraging 3M Material Science & Competence on a global Scale



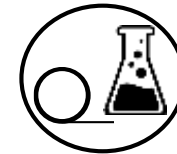
Automotive



Consumer
Electronics



Energy



Tapes &
Adhesives



Balancing Battery Pack Design with new Regulations

Standards & Regulations

ECE100

31467

J2464

GTR 20

NN....

NFPA 855



Design Goals

Range

Weight

Size

Cost

Assembly

Life-time

- Growing number of new and revised EV Safety Regulations and Standards
- Challenge to balance between competing Design Goals in the new Regulatory Environment

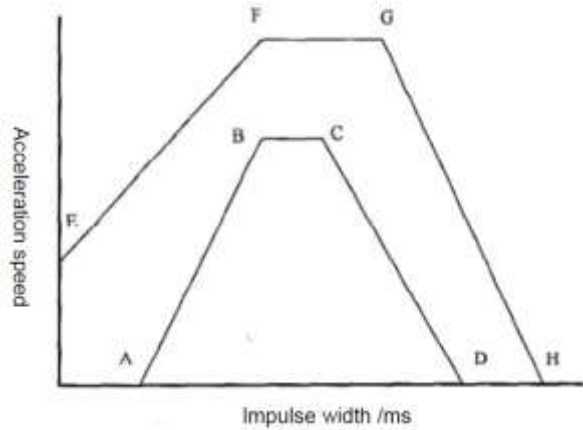
Matching the Standards can be very challenging

Abuse Tests	International					USA			EU		India	Korea	China	
	SAE J2464 - 2009 [1]	SAE J2929- 2013 [2]	ISO 12405 -1(2) - 2011(2012) [11] [12]	ISO 12405- 3 - 2014 [5]	IEC 62660 - 2 -2010 [3]	UL 2580 - 2016 [6]	USABC - 1999 [13]	Freedom CAR - 2006 [4]	UNECE R100.02 - 2013 [10]	UN 38.3 - 2015 [8]	AIS-048 - 2009 [7]	KMVSS - 2009 [14]	GB/T 2423X - 2018	QC/T 743 - 2006 [15]
Mechanical														
Mechanical shock	●	●	●	●	●	●	●	●	●	●	●		●	
Drop	●	●				●	●	●				●	●	●
Penetration	●						●	●			●		●	●
Immersion	●	●		●		●	●	●				●		
Rotation	●	●				●	●	●			●			
Crush	●	●		●	●	●	●	●	●	●				●
Vibration		●	●	●	●	●	●	●	●	●	●			●
Electrical														
Over-charge	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Over-discharge	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Short circuit	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Thermal														
Over heating	●	●				●	●		●					
Thermal shock	●	●	●	●	●	●	●	●	●					
Thermal stability	●				●	●	●	●				●		●
Environmental														
High temperature	●	●		●		●	●	●	●			●		

- Extensive Series of regional and global Tests to be considered for Battery Pack Design.
- Standards are quickly evolving to include new Concerns – Thermal Propagation & Recycling.

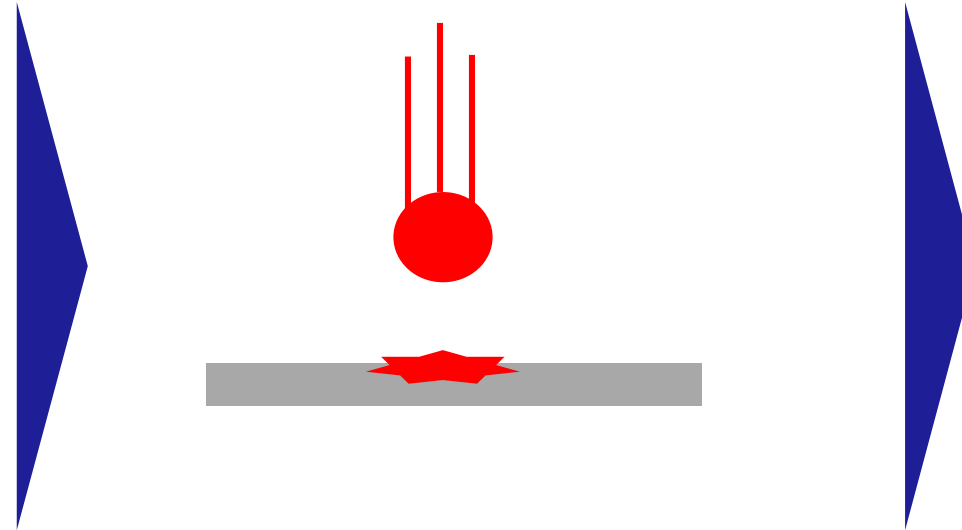


Translation of System Standards to Material Properties

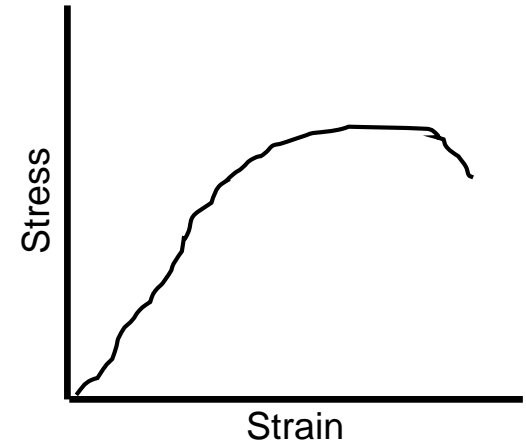


Acceleration speed vs Impact for
Battery Pack (GBT 31467.3)

Standard Requirements



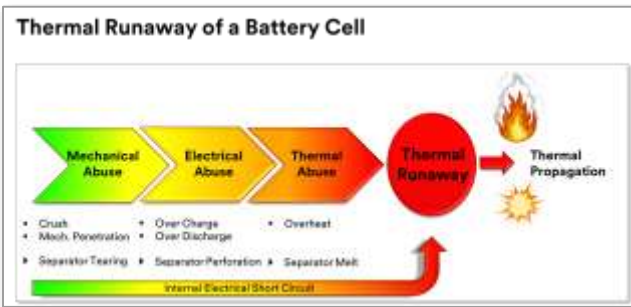
Representative Testing



Material Properties

- Traditional mechanical Requirements (Impact, Vibration) readily translate to Material Requirements.
- With newer Battery Requirements (Thermal Propagation, Recyclability, Venting Gas Mgmt.) the Translation to Material Properties needs to be developed.

Thermal Propagation Protection



Thermal runaway mechanism of lithium ion battery for electrical vehicles, Xining Feng @ al., Elsevier B.V. 2017.

- UN GTR 20 Regulation:
 - Safety Time Buffer: 5 Minutes after warning
 - TP Test passed: No visual fire or explosion at module- or battery level
- UN GTR 20 is focusing on Module or Pack Level Testing

Distilling Thermal Runaway into Material Properties

Thermal Runaway Initiation

External heating
Over-charging
Over-discharging
Structural damage
External short
High current charging



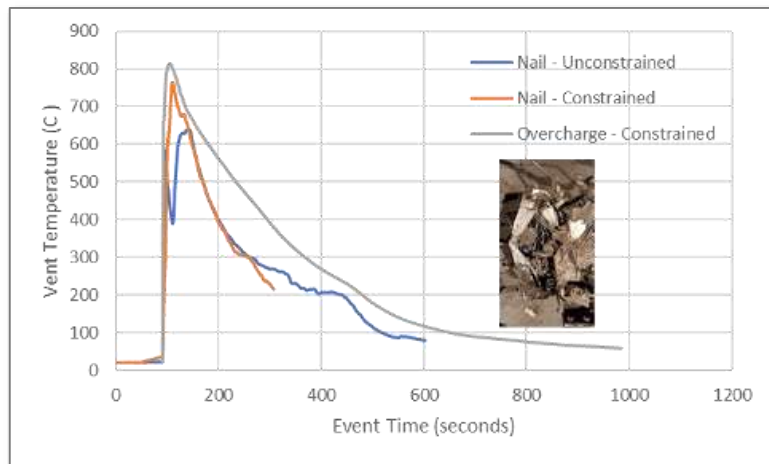
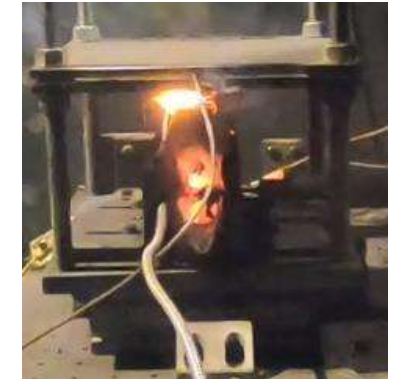
High Temperature & Flames



Aggressive Particles



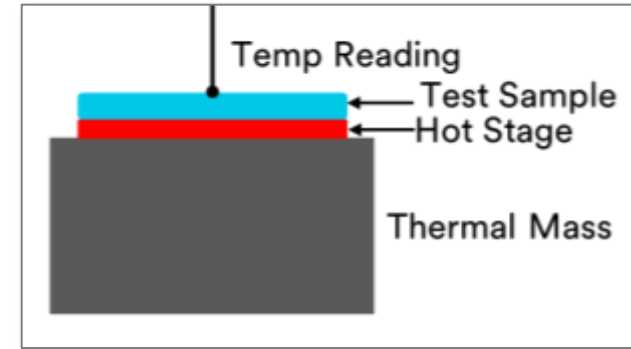
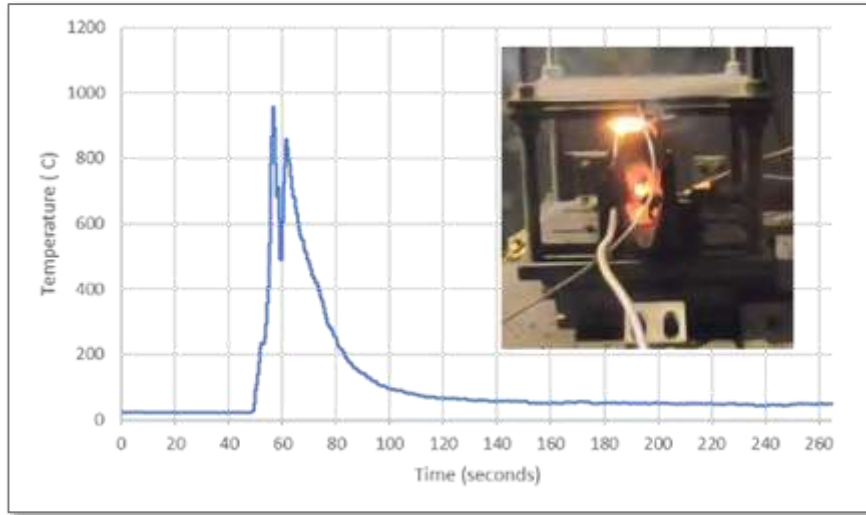
Radiative Heat



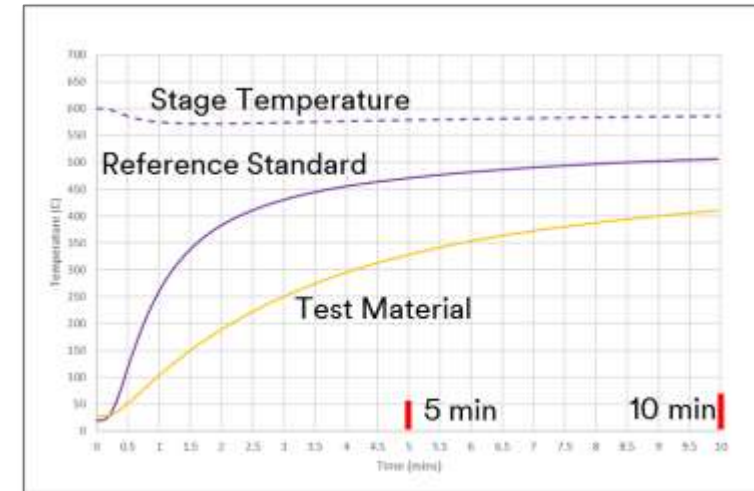
- System can start in many states:
 - State of charge, Aged Chemistry, Battery Age
- Rapid Changes in a complex System result in Measurement Challenges.
- Focus in PreLIBS on the observed rapid Temperature Rise.

Thermal Propagation between Cells

HCS Hot & Cold Side Test



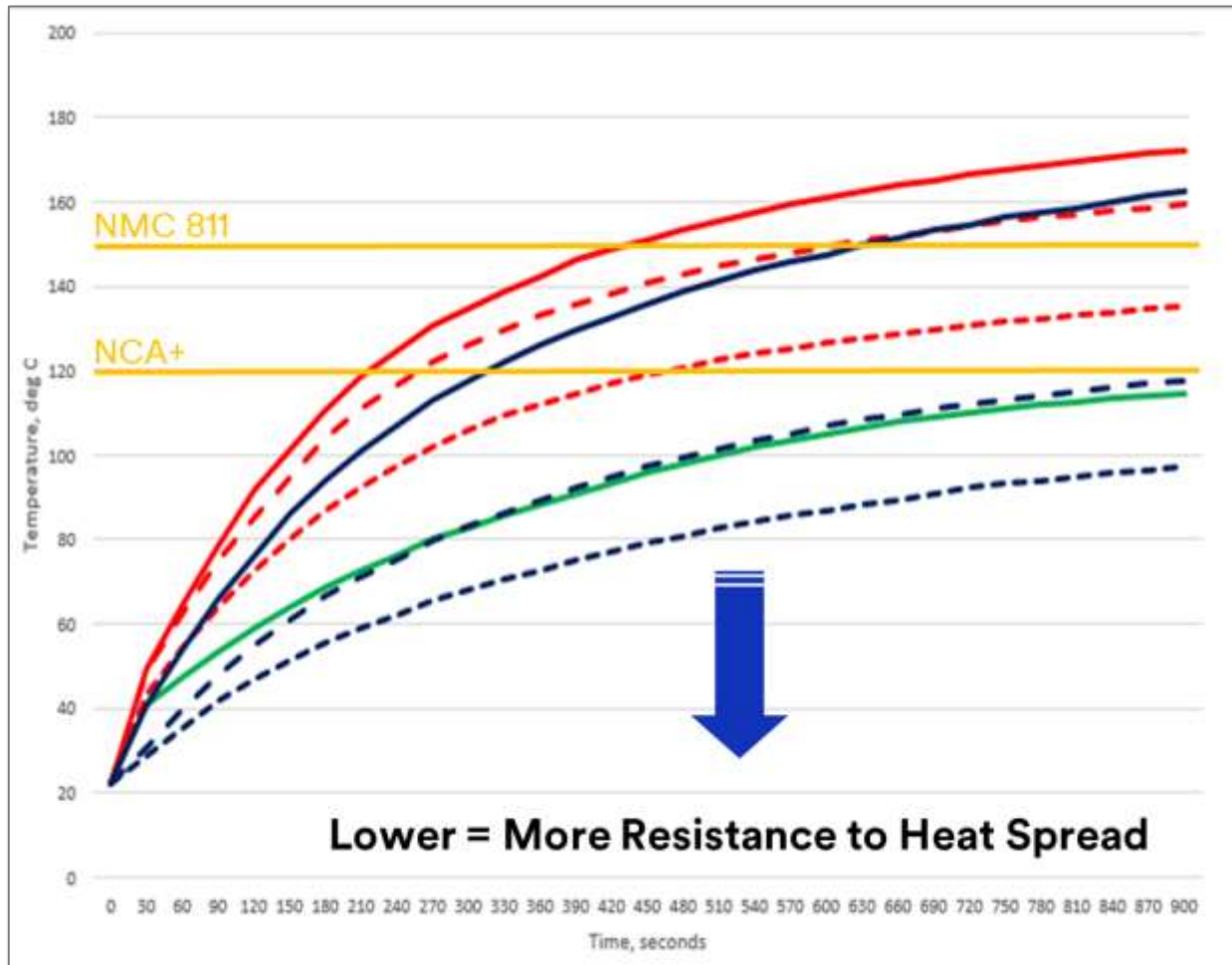
- Temperatures can exceed 800°C in under 30 sec.
- Peak temperature is followed by temperature decay until cooled down or adjacent cells go into runaway.
- Exact temperature profile is system dependent.



- HCS Test Setup to simulate rapid Exposure of Prototype Material to Thermal Runaway Condition.

HCS Test Results for improved Insulation Performance

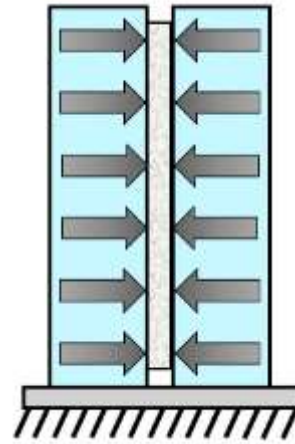
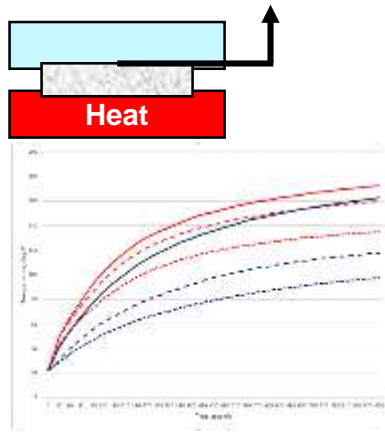
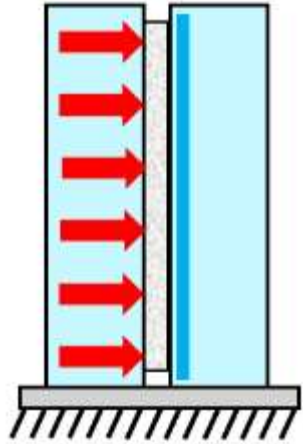
HCS Test - Rapid Exposure to Hot Surface



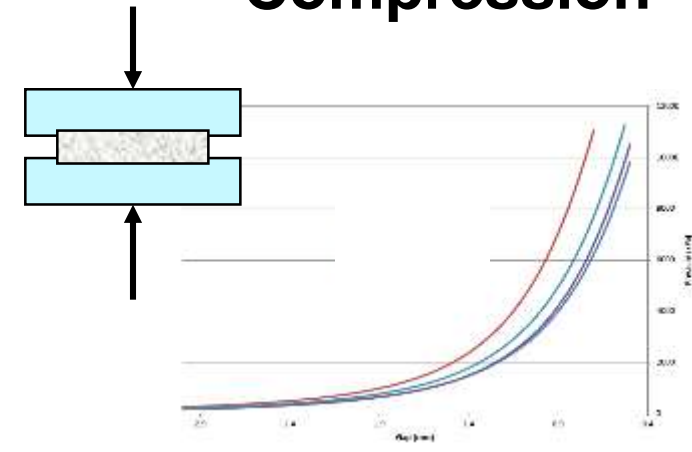
- Understanding the Cold Side Temperature as a Function of Time gives Insight into Thermal Spread.
- Similar to a Thermal Conductivity Measurement but allows for Evaluation of Solutions not purely Thermal.
- Allows for rapid Screening of Solutions to help understand Impact of Solution Construction on End-performance.
- Increased Time to a set Temperature is expected to translate to reduced Heat Spread to Cells.

Designing for Life - Thermal Exposure is not enough

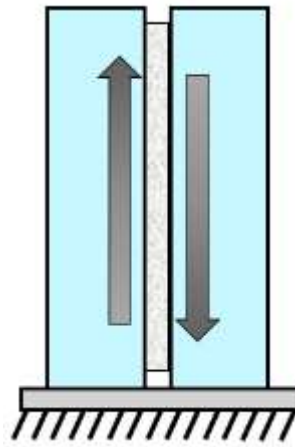
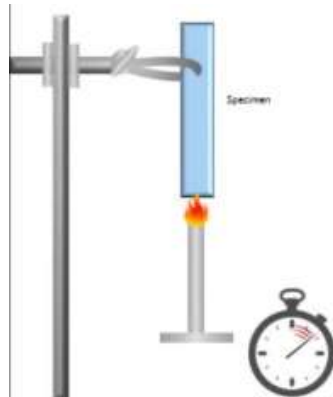
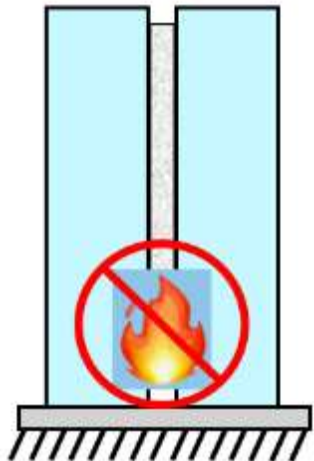
Thermal Exposure



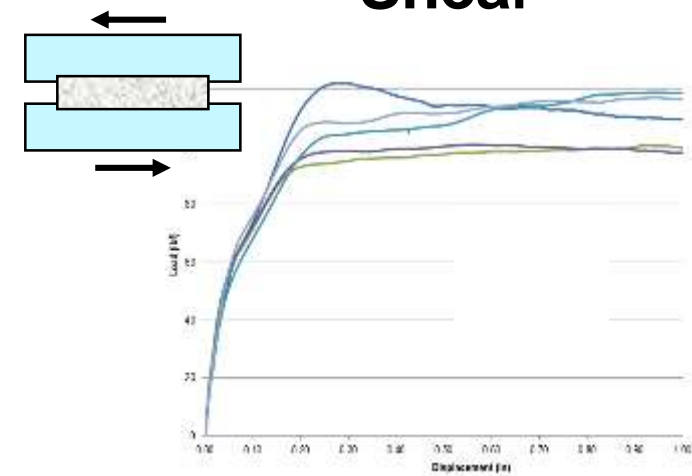
Compression



UL94 V0



Shear

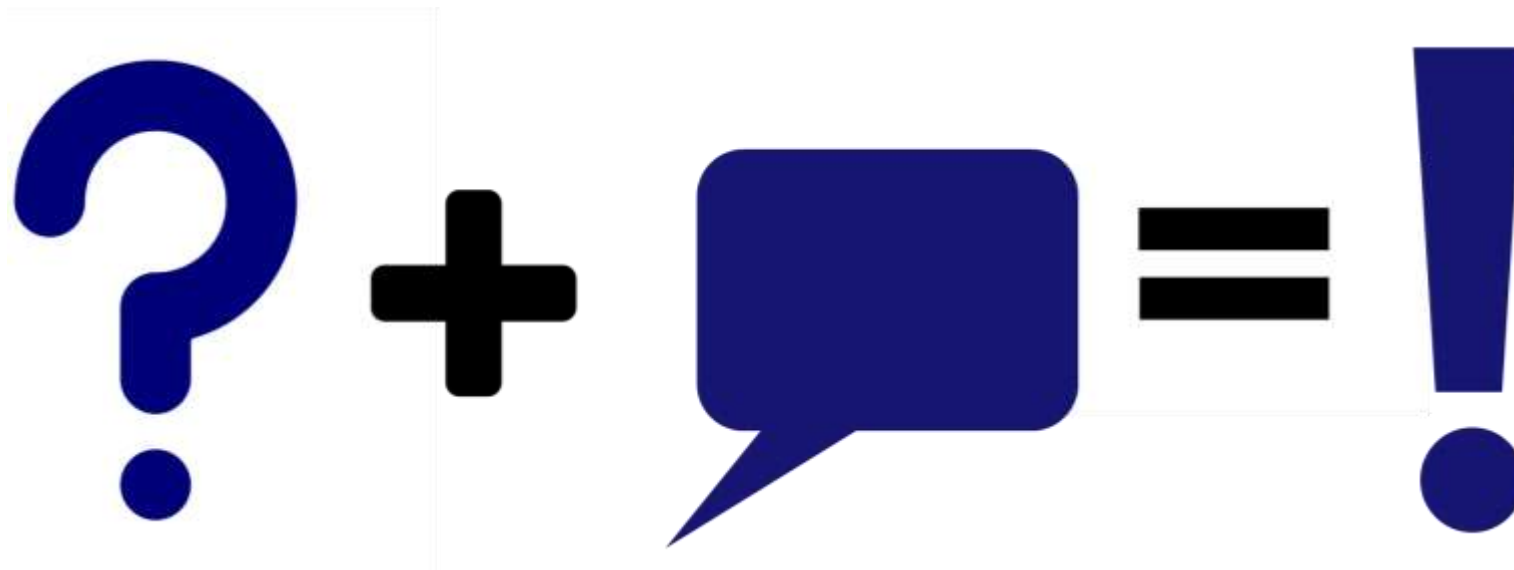




Summary

- GTR 20 as new leading Regulation for Electrical Vehicle Safety
- Increased global & local Efforts to translate System Standards to Material Properties
- 1st Testmethod to evaluate the Heat Spread between Cells
- Continued Research to design additional Test Methods for Material Development slowing down Thermal Propagation

Q & A





Thank You !

The image features the 3M logo in red on the left, followed by the tagline "Science. Applied to Life.™" in black. The background is white on the left and transitions into a blue geometric shape on the right.

3M Science.
Applied to Life.™