

BATTERY SENSORS

THERMAL RUNAWAY DETECTION

Regensburg, April 2021

Philippe Grass

Sensing & Actuation, Advanced Development Sensors

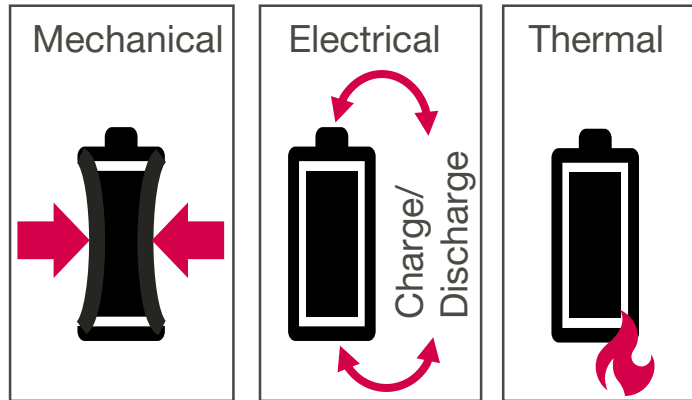
Public

THERMAL RUNAWAY / PROPAGATION DETECTION

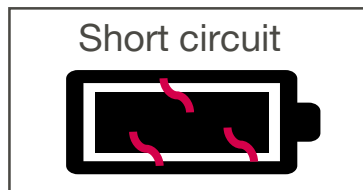
THERMAL RUNAWAY

Runaway initiation

- > External factor

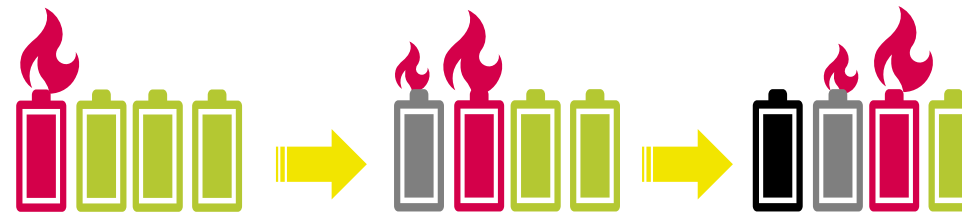


- > Internal malfunctions (dendrites, separator)



Runaway start

- > Event triggered (active driving, charging)
- > Anytime, **time delayed** to event (active and off / parking mode)



Thermal propagation from cell to cell once started

Hazardous situation

- > Timing depends on the way the cells are packaged



THERMAL RUNAWAY / PROPAGATION DETECTION

THERMAL PROPAGATION – GTR20 PHASE 1 REGULATION SUMMARY

Which vehicles:

Area of application: vehicle battery cells with flammable electrolyte

Safety target:

- > Prevent vehicle occupants from hazards (gas, smoke, fire, explosion, electrical shock,...)
- > Venting gas management (venting valves, pressure release)
- > Prevent occupant from gas emission hazards
 - > Electrolyte vaporization: low danger
 - > Electrolyte combustion/decomposition: high danger

Detection requirement:

- > Detection of first single cell runaway (signs: voltage drop, absolute temperature, temperature rise,...)
- > TP test to prove and document TR performance with single cell initiation

Warning requirement:

- Only required in “Active driving possible mode”**  **Park mode not addressed by regulation**
- > State of vehicle movement by electric powertrain by pressing acceleration pedal or releasing brake pedal
 - > Meaning: automatic transmission in **D/S or R** position (drive/sport or reverse), **not in N or P** (neutral or parking)

Meet req. / prove in testing:

- Thermal propagation requirements met if:
- > Pack level: After warning provide 5 minutes without external fire or explosion
 - > Vehicle level: After warning provide 5 minutes without external fire or explosion and no smoke in the passenger cabin

Source: <https://unece.org/transport/standards/transport/vehicle-regulations-wp29/global-technical-regulations-gtrs>

BATTERY SAFETY LEGISLATION

LEGISLATION – WORLDWIDE AS OF APRIL 2021

GTR20 Phase 1 adoption schedule worldwide

	2020												2021												2022												2023											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	Homologation start												effective																																			
China						◆																																										
Japan													amendments of UN R100 National adoption under consideration																																			
Korea													effective																																			
India																																					effective											
USA	Proposal for implementation expected in 2021																																															
Canada	Waiting for end of phase 2 before assessing timeline for implementation																																															
EU	Implementation in R100, no official timing found																																															

Source: <https://wiki.unece.org/pages/viewpage.action?pagelD=3178628>

United Nations Economic Commission for Europe
(UNECE)

Global Technical Regulation No. 20 (GTR20)

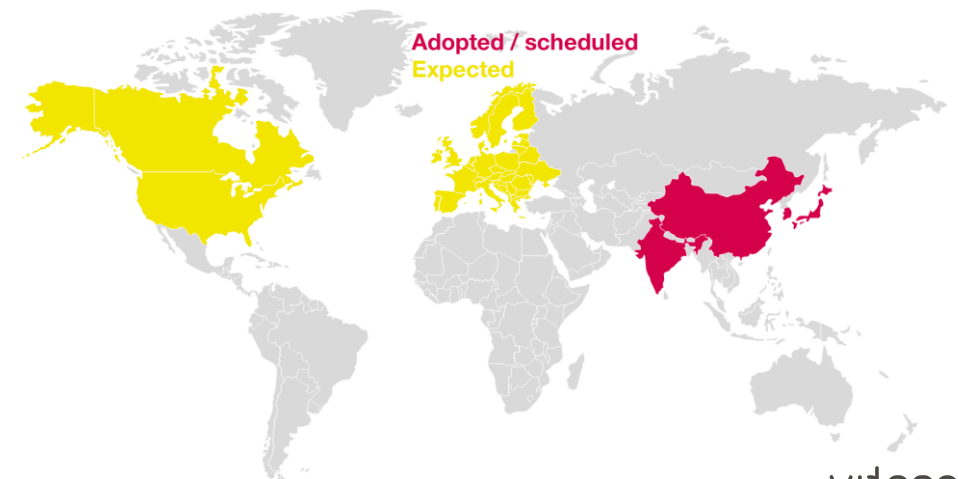
Global Technical Regulation on Electric Vehicle

Safety (EVS)

- > Phase 1 finished / established on 14 March 2018
- > Phase 2 ongoing / not finished

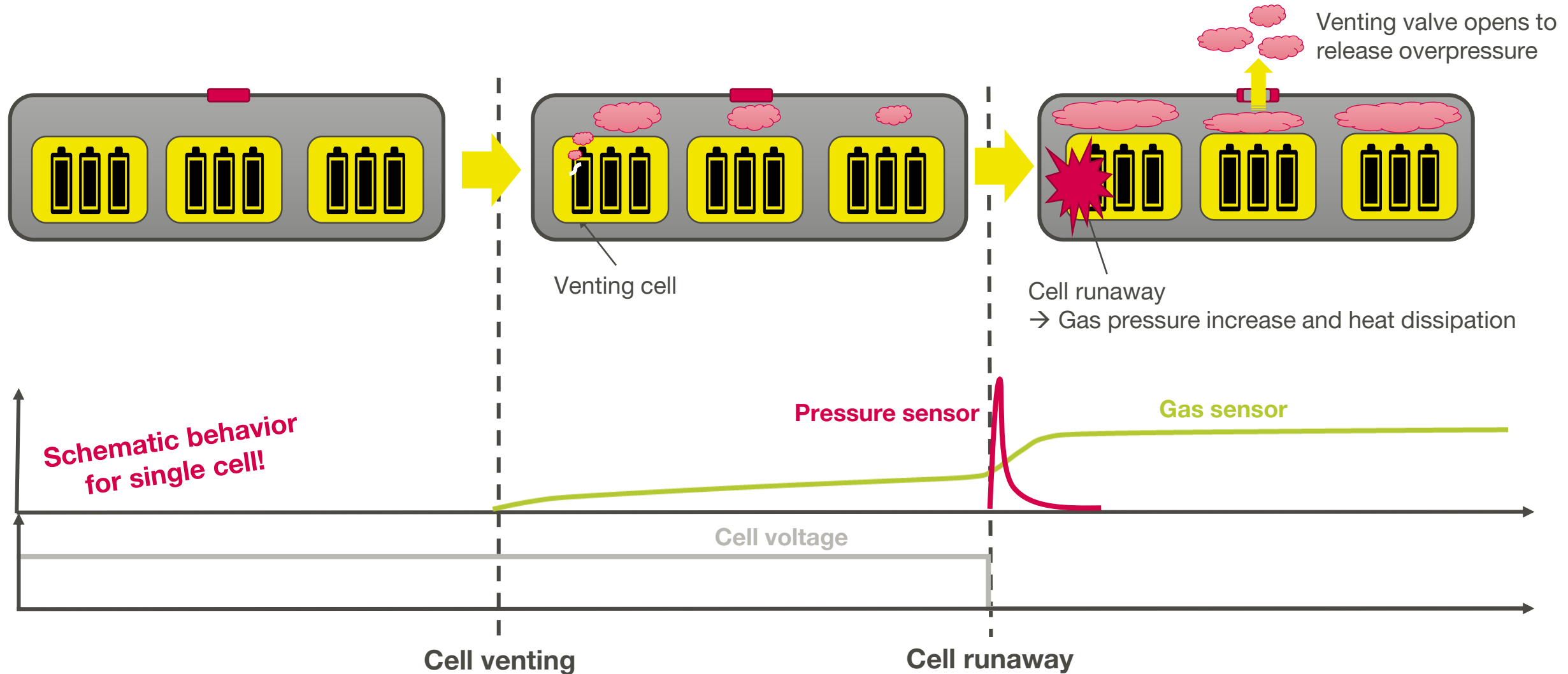
Link:

<https://unece.org/transport/standards/transport/vehicle-regulations-wp29/global-technical-regulations-gtrs>



THERMAL RUNAWAY / PROPAGATION DETECTION

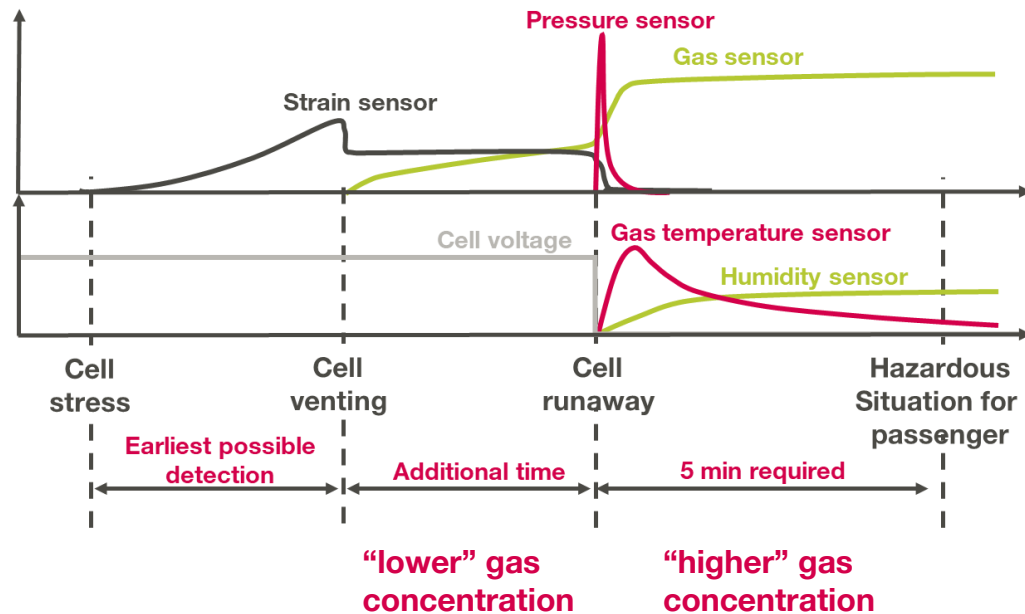
THERMAL RUNAWAY DETECTION SYSTEM – SENSOR SIGNALS



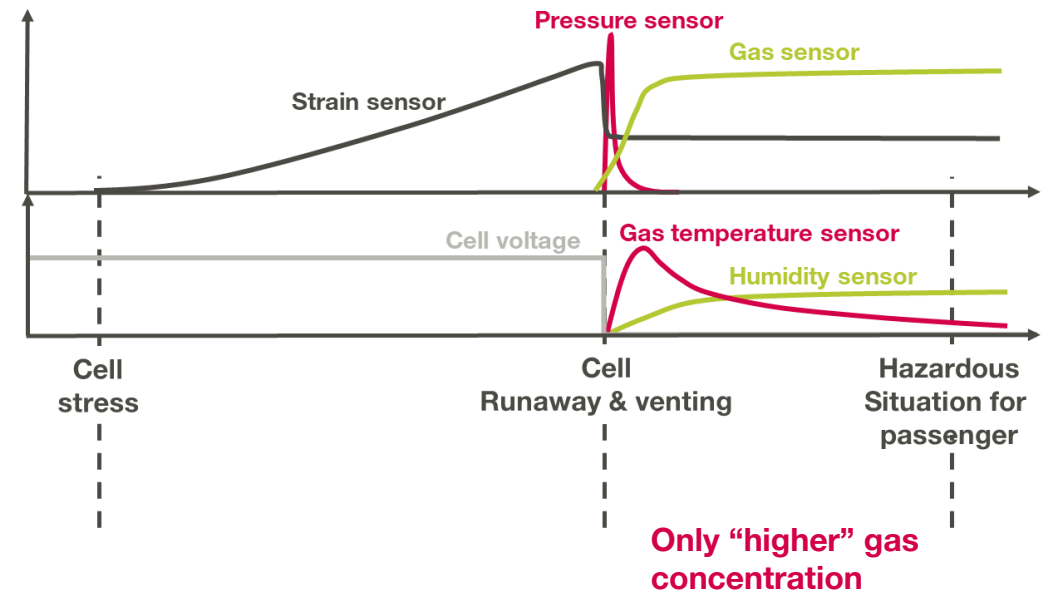
THERMAL RUNAWAY / PROPAGATION DETECTION

RUNAWAY DETECTION TIME SEQUENCE DEPENDING ON CELL TYPE

Schematic for pouch cell



Schematic for prismatic/cylindrical cell



The cell venting can occur earlier or at the same time than the cell runaway, offering a time advantage to the Gas measurement compared with Pressure measurement only

THERMAL RUNAWAY / PROPAGATION DETECTION

USE CASES – BATTERY RUNAWAY DETECTION

Driver / Use Case	Explanation / Comment	(possible) solution	Maturity @ OEM and Vitesco
Today's Legislation	Detection of thermal event in "active driving possible mode"	<ul style="list-style-type: none"> > BMS (voltage, current, temperature), > Analog pressure sensor 	In series production, First generation
Specific OEM safety target	Anytime <ul style="list-style-type: none"> > Vehicle state: charging, parking mode, ... > Wake up functionality, signal shape analysis, memory.. 	> Smart pressure sensor	Planned for next battery platforms 2024, 2 nd generation in development with OEMs
	Earlier detection <ul style="list-style-type: none"> > Harder time goals > 5 min before hazardous situation: venting before runaway 	> Smart gas sensor*	
Other cell chemistry	"Slow" venting/runaway, burning of battery without pressure peak possible	> Smart gas sensor*	3 rd generation gas sensor (Long term stability, ASIL), under predevelopment with OEMs
Improve safety beyond runaway detection	Detection of combustible atmosphere in battery pack , for example with usage of open contactors (Sparking risk)	<ul style="list-style-type: none"> > Smart pressure sensor if gas only possible after runaway (hard cover cells)* > Smart gas sensor* 	

* Or a combination of principles Pressure + Gas to realize redundancy

THERMAL RUNAWAY / PROPAGATION DETECTION

SUMMARY

- > Runaway Start can occur Instantaneous or Time delayed to the event trigger.
- > Legislation covers the detection only when the vehicle is operated. Time slots when the vehicle is parked for example are a white spot.
- > Thermal event physical characteristics (Pressure peak, Gas relief) depend on cell type, cell chemistry, system topology and root cause.
- > Short term solution to fulfill runaway detection in any condition is a Smart Pressure Sensor (2024+).
- > Mid & Long-term solution to cope with more stringent time safety goals is to add a Gas sensor (2026+).