Environmental simulation tests

Environmental simulation equipment for e-mobility

Agenda

Environmental factors

Objective of environmental simulation tests

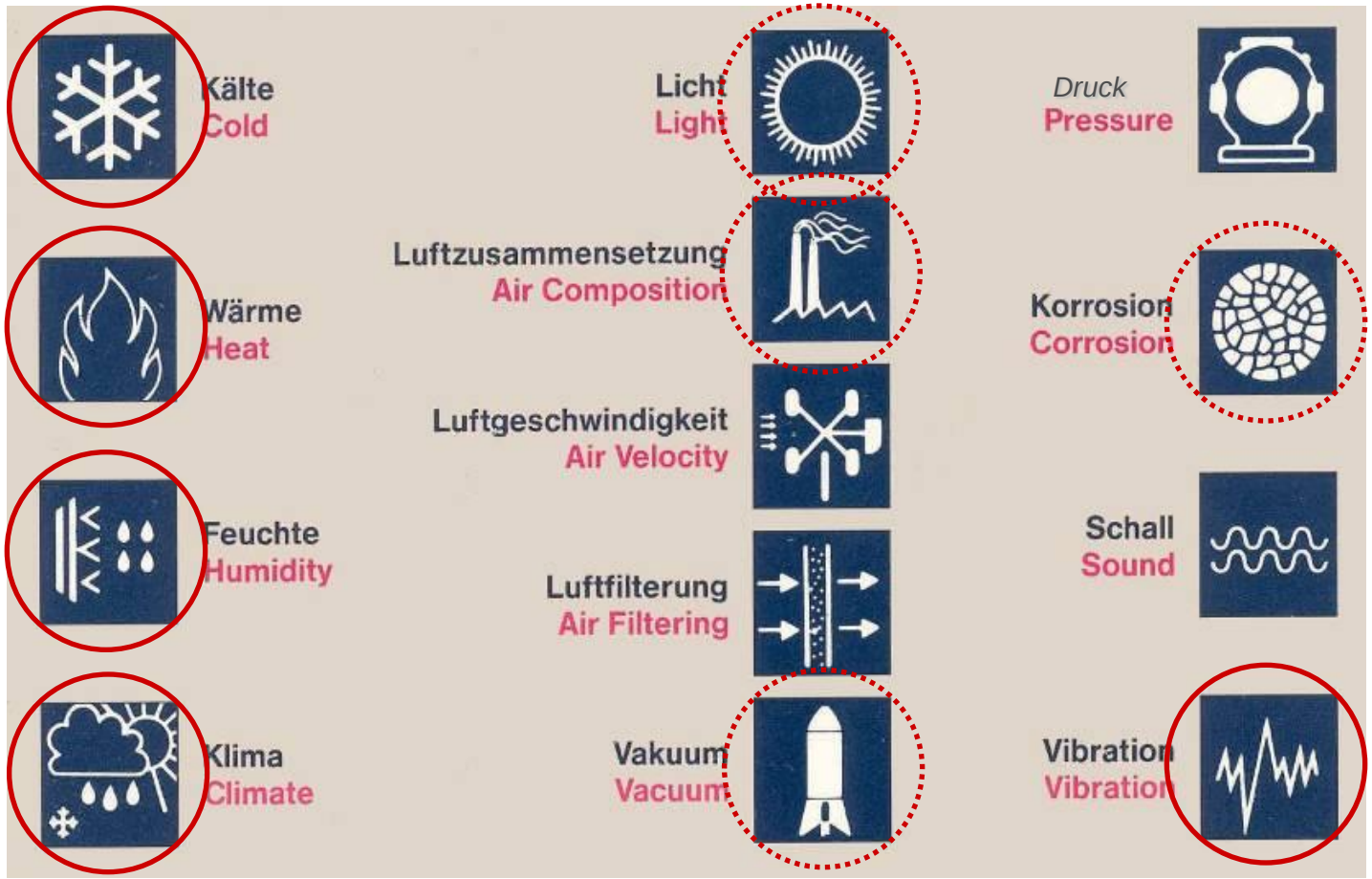
Range of technologies for e-mobility

Environmental simulation equipment for e-mobility to test:

- **Power Control**
- **Cables and connectors**
- **Li-ion Batteries**
- **Electric Drive**
- **Fuel-Cell**

Environmental simulation tests

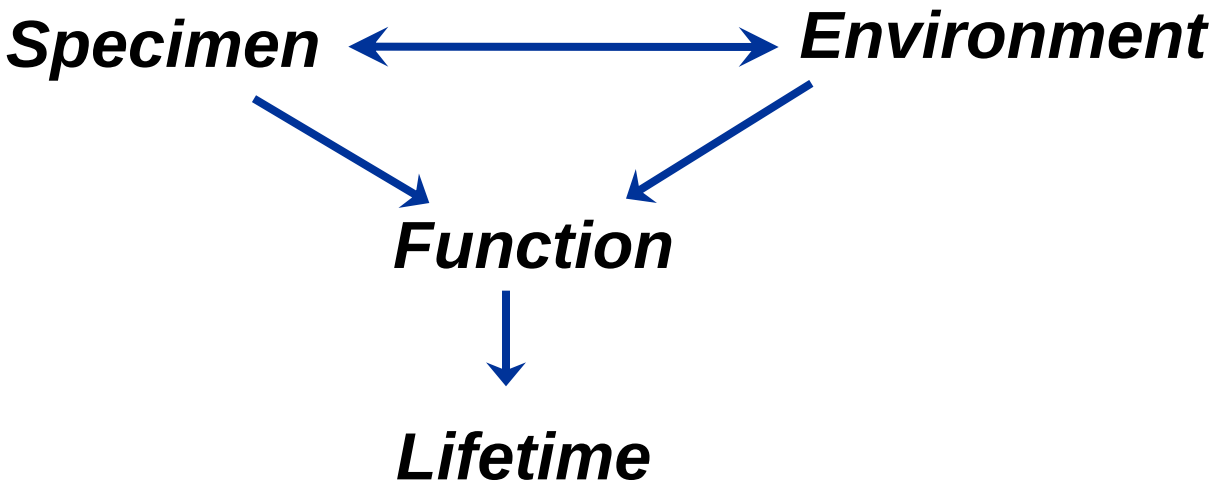
Environmental factors



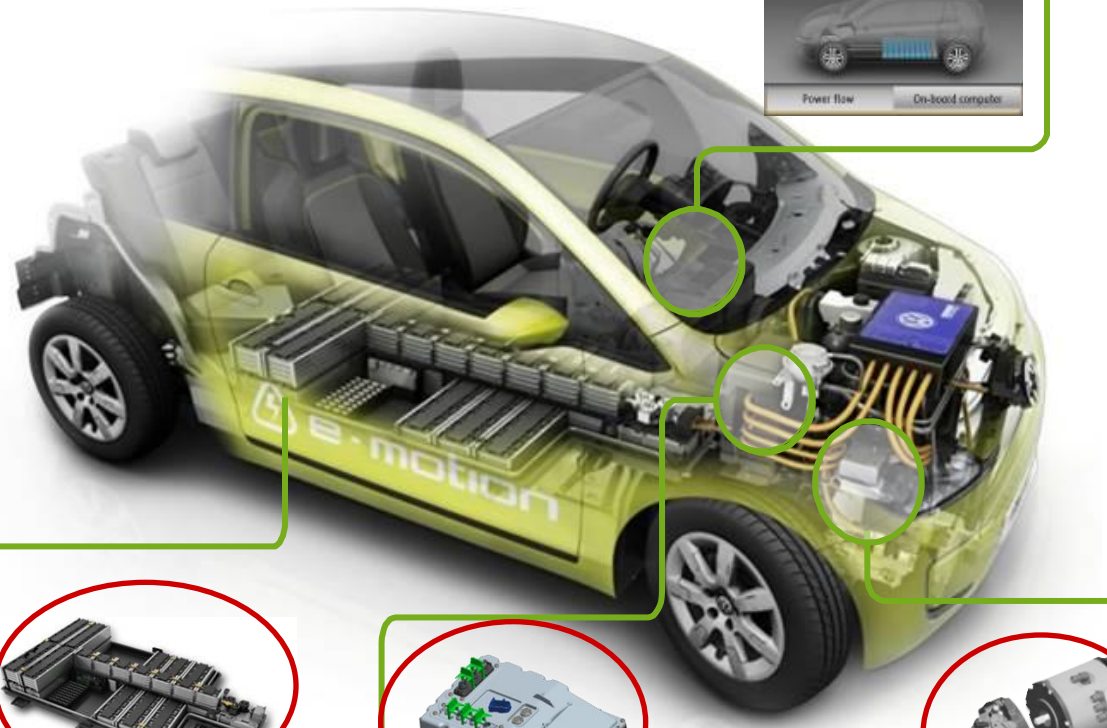
Environmental simulation tests

Objective of environmental simulation tests

- Systematic investigation of the interaction between the specimen and the enviroment
- Statements about the lifetime



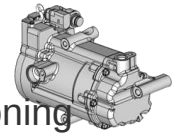
Range of new technologies for electric vehicles



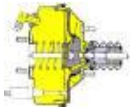
infotainment

remote-control/online services

heating



air conditioning



e-brake booster

High-voltage cable

Traction battery and battery management

power control

e-motor and gearbox

Agenda

Environmental factors

Objectives of environmental simulation tests

Range of technologies for e-mobility

Environmental simulation equipment for e-mobility to test

- Power Control
- Cables and connectors
- **Li-ion Batteries**
- Electric Drive
- Fuel-Cell

ISO 12405-2

Table A1: Assignment of tests to battery pack and system

	Performance						Reliability				Abuse		
Test Procedure	Energy & Capacity	Power & Internal Resistance	Energy Efficiency at Fast Charging	No Load SOC Loss	SOC Loss at Storage	Cycle Life	Dewing	Thermal Shock Cycling	Vibration	Mechanical Shock	Short Circuit	Overcharge Protection	Overdischarge Protection
Battery system (Battery pack with integrated BCU)													
System	X	X	X	X	X	X	X	X	X	X	V	V	V
Battery system (Battery pack with external BCU)													
System	X	X	X	X	X	X	-	-	-	-	V	V	V
Pack *1	U	U	-	-	-	-	X	X	X	X	W	-	-

*1 BCU not included, external BCU not operating, cooling not operating, main contacters controlled manually

X	relevant test
-	test not relevant
U	adapted / reduced procedure
V	functional test including active BCU
W	fuse test

Test under the influence of temperature

external influences

- external heating
- overloading
- deep discharge
- Excessive charging current
- External short-circuit

internal events

- Electrode electrolysis reactions
- Electrochemical reactions

Heat generation

> heat dissipation

impacts

- Protection system works
- Defect
- Leckage
- Venting
- Fire or Flame
- Rupture
- Explosion

EUCAR Hazard Levels

European **C**ouncil for **A**utomotive **R**&D

Hazard Level	Description	Classification Criteria & Effect
0	No effect	No effect. No loss of functionality.
1	Passive protection activated	No defect; no leakage; no venting, fire or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell reversibly damaged. Repair of protection device needed.
2	Defect / Damage	No leakage; no venting, fire or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell irreversibly damaged. Repair needed.
3	Leakage Δ mass < 50%	No venting, fire or flame*; no rupture; no explosion. Weight loss <50% of electrolyte weight (electrolyte = solvent + salt).
4	Venting Δ mass ≥ 50%	No fire or flame*; no rupture; no explosion. Weight loss ≥50% of electrolyte weight (electrolyte = solvent + salt).
5	Fire or Flame	No rupture; no explosion (i.e., no flying parts).
6	Rupture	No explosion, but flying parts of the active mass.
7	Explosion	Explosion (i.e., disintegration of the cell).

Laboratory safety test

Purpose of the test

- **Is the Personal safety secured.**
  Evidence that shows that the safety devices are sufficient

- **Building protection and Property protection**

  Evaluation of an attack on adjacent test benches or the building

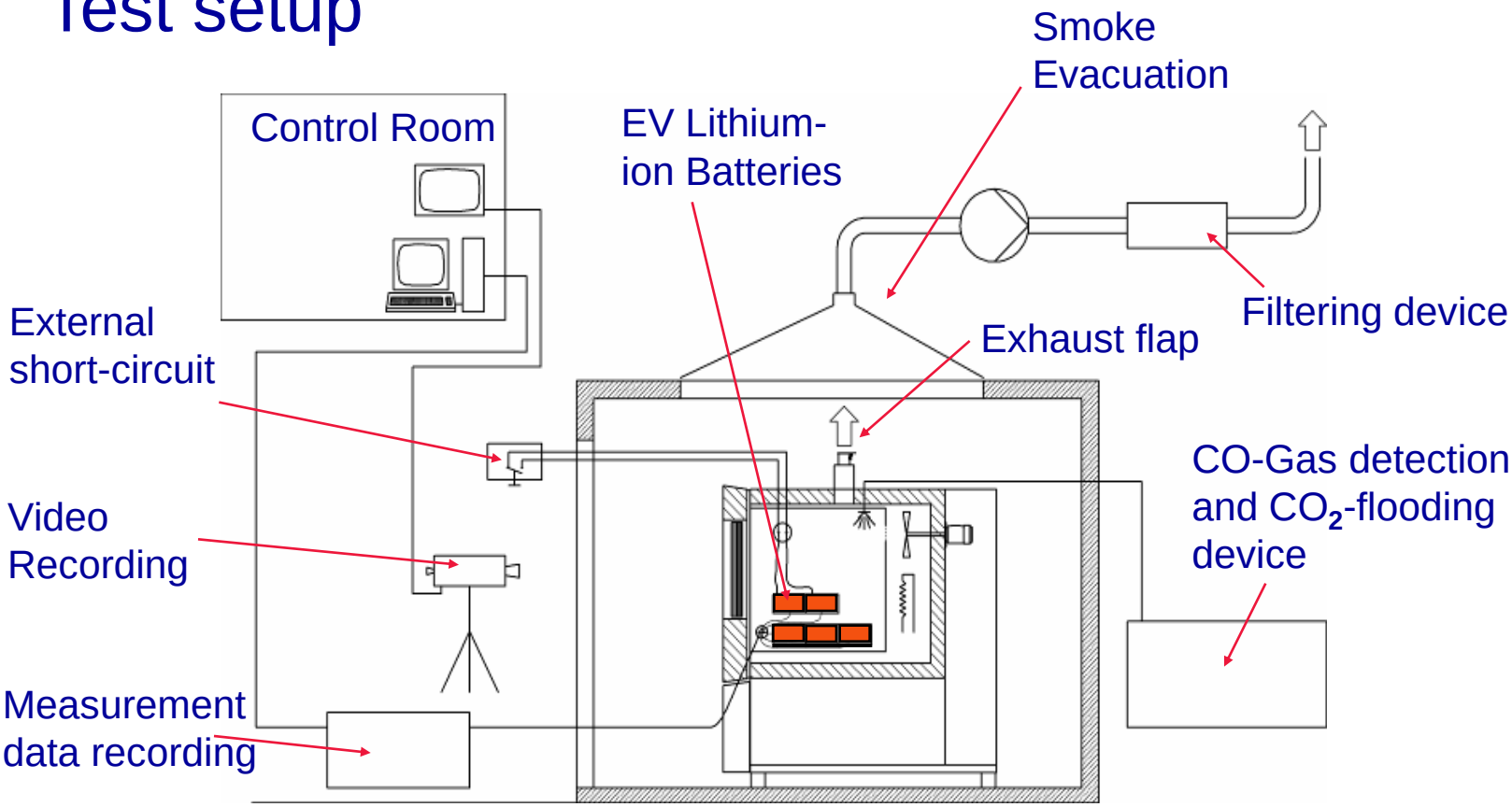
Laboratory safety test

Questions and thoughts before the test?

- Inside the test cabinet
  - How many cells are simultaneously activated by the short circuit to the thermal runaway?
  - Is the pressure compensation for resultant gas quantities large enough?
  - What temperatures / pressures can we expect?
  - Is there a chance of an explosive reaction in the beginning?
  - Where is the released energy going to?
- Outside the test cabinet
  - What quantities of gas are released out of the chamber?
  - Will there be a fire outside the chamber?
  - What is the risk that the bottom of the chamber will melt and collapse?

Laboratory safety test

Test setup



Laboratory safety test

Experimental house for fire

Smoke Evacuation

Brick Wall

Temperature test cabinet module

Side view

Front view

Laboratory safety test

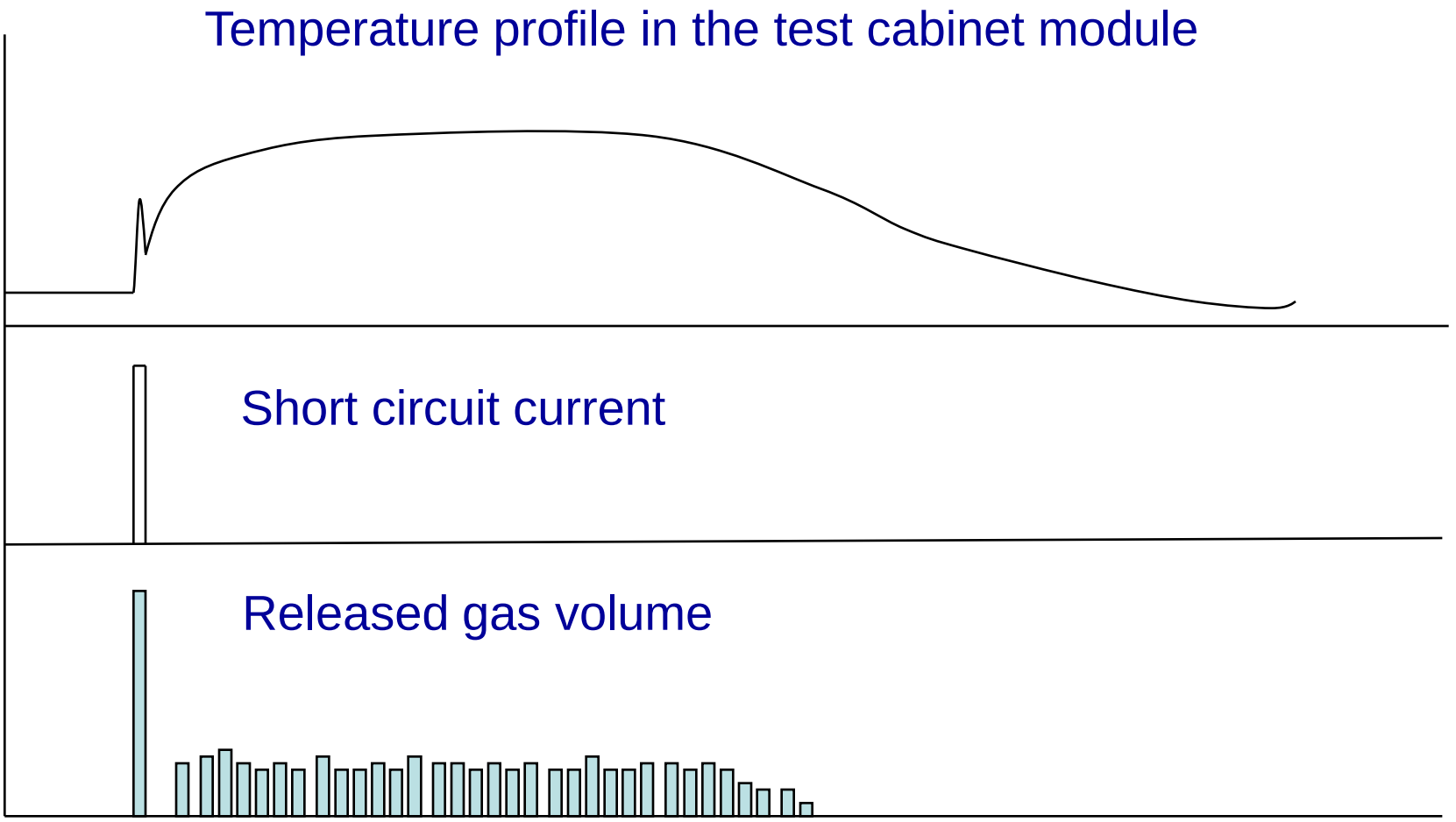
Test severity: Worst Case

- 2 pieces EV Lithium-Batteries 29 kWh Total output
- without cover, 100 % SOC
- All security organs of the battery are overriden
- Temperature in the test cabinet module + 65°C/ 150°F

Triggering the accident

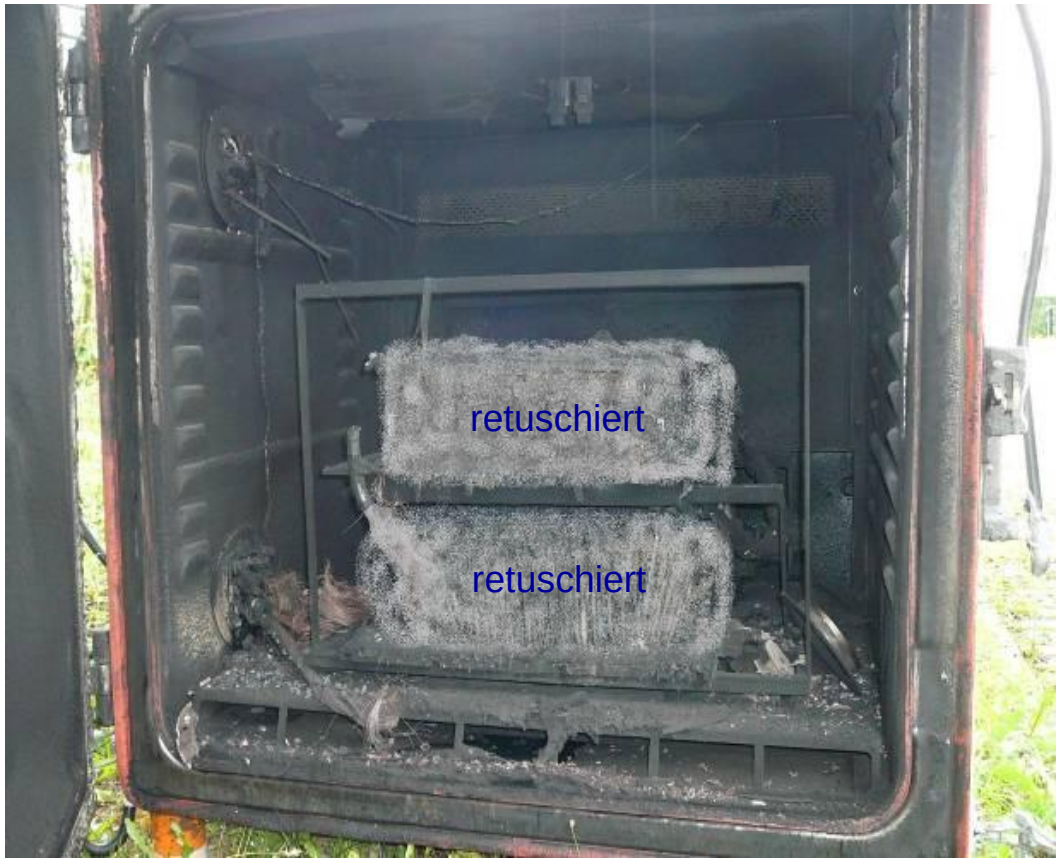
External short-circuit

Laboratory safety test



Laboratory safety test

Condition after the test



State of the test cabinet
2 days after the test

Laboratory safety test

Results

- Starting with violent reaction and a release of large quantities of gas
- As a follower action, more cells will be activated sequentially
  - Domino effect-
- It comes to a smoldering
- Air temperature in the test cabinet module rises up +600°C / 1100°F
- The temperature test cabinet module is resistant to the stress
- Only gases penetrate to the outside -no fire-
- Test Personal are safe
- There will be no attack on adjacent facilities / buildings

Laboratory safety test

Finding

Basic security measures for a test chamber

- Correct dimensioned pressure compensation
- Secure door lock system

Additional devices to further reduce risk

- N2 inerting
- Gas measurement warning
- CO2 and inerting and cooling

Laboratory safety test

Comment

- Derivation of the corrosive and toxic gases is the central task in the building
- Results can only be considered as indicative values to other constellations
- Battery chemistry and design have strong influence on the accident
- It is possible to clean the test room?
- Test cabinet modules have been disposed of as hazardous waste

Li-ion safety equipment (options)

Reversible pressure release flap

Alternative: Pressure release via burst disk
incl. pressure resistant inner container

Optic and acoustic alarm

Fire detection by CO gas measuring

N2 - Permanent-Inertisation
O2 – gas measuring

Electric door lock

Mechanical door lock

CO2 Flooding

Example 1

Temperature chamber

- For testing cells and modules
- Per test room 210 liter
- Temperature range: -40°C … +180°C
- Rate of change: ca. 3 K/min
- Heat compansation: 1000 W

- safety equipments:
  - Electrical and mechanical door lock
  - Pressure release flap
  - N2 Inertisation
  - Pressure monitoring of the chamber

Example 2

Climatic chamber

- For testing modules and packs
- Test room 180 … 1500 liter
- Temperature range: -70/-40°C … +180°C
- Rate pf change: 2 … 15 K/min
- Heat compensation: 1 KW - 8 KW
- Safety equipments:
  - Electrical and mechanical door lock
  - Pressure release flap
  - CO measurement / CO2 flooding

Example 3

Climatic chamber

- For testing large batteries
- Test room 6000 liter
- Temperature range: -70/-40°C … +120°C
- Rate of change: ca 2 K/min
- Heat compensation: 5 KW
- Safety equipments:
  - Electrical and mechanical door lock
  - Pressure release flap
  - CO measurement / CO2 flooding

Example 4

Walk-in chamber

- For testing large batteries
- Test room 8000 liter
- Temperature range: -50 … +95°C
- Climatic range: 10%r.h. … +90%r.h.
- Rate of change: 2 K/min
- Heat compensation: 10 KW
- Safety equipments:
  - Electrical and mechanical door lock
  - Pressure release flap (Hot gas up to 800l/s)
  - N2 permanent Inertisation
  - O2 Measuring

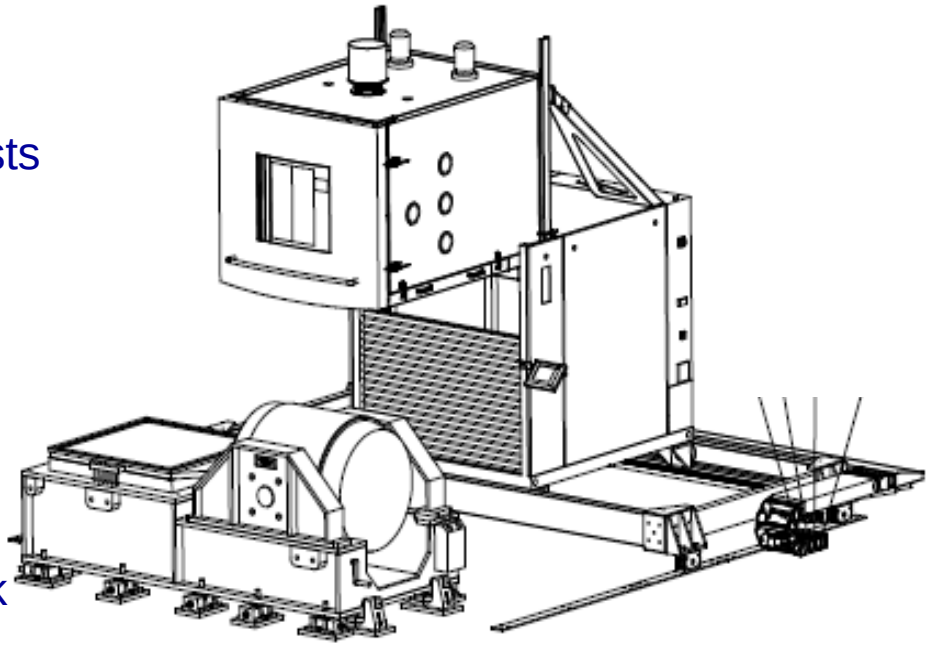
Example 5

Drive in chamber

- For testing EV (electric Vehicle)
- Test room: 53m³ (4,0x6,0x2,2m)
- Temperature range: -60 … +150°C (90°C)
- Climatic range: 10%r.h. … +90%r.h.
- Rate of change: 1 K/min
- Heat compensation: 35 KW
- Safety equipments:
  - Electrical and mechanical door lock
  - Fresh air purge unit / Pressure release flap
  - N2 permanent Inertisation / O2 Measuring
  - H2 and CO Measuring

Example 6

Vibration chamber



- For vibration and temp. combination tests
- Test room 2200 liter
- Temperature range: -70 … +180°C
- Rate of change: 22 K/min
- Heat compensation: 8 KW
- Safety equipments:
  - Electrical and mechanical door lock
  - Pressure release flap 200mm
  - N2 permanent Inertisation
  - CO Measuring and preperation for CO2 cooling

discussion

Environmenat simulation equipment for e-mobility