



Good engineering practice in FS Accumulator Design

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Most important rules changes

EV 5.5.2 **Impact Protection of TSAC**

- The TSAC(s) must be protected **from impacts, see T3.15**, and must follow T3.16 when having bolted attachments. The TSAC must not be part of this structure.

Intent

Simplified/generalized wording.
See SES presentation.



Most important rules changes

EV 5.5.3 **Non-metallic TSAC materials**

- All TSAC materials as well as all structural parts **used to comply with EV5.5.8** must be fire retardant, see T1.2.1. **All calculations must be conducted for an ambient temperature of 60 °C except for metallic materials and continuous fiber-reinforced laminates.**

Intent

Better design of TSAC parts concerning thermal properties.



Most important rules changes

EV 5.5.10/11 **Handling of (pouch) Cells**

- Pouch cells must be fixed using at least 80 % of each large surface. Tabs of pouch cells must not carry mechanical loads and must not press into the pouch.
- Friction-based cell mounting requires physical testing and must be documented in the SES.

Intent

Give more guidelines for cell stack design. Improve safety, especially of pouch cells.

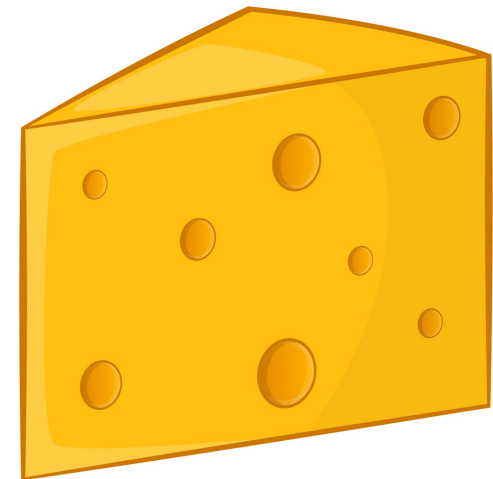
Most important rules changes

EV 5.5.15 **Cutouts in TSAC walls**

- The total cutout area must be below 25 % of the respective single wall.

Intent

Prevent unsafe designs. Protect cell stacks from each other.



Most important rules changes

S3.4.6 Cells for design event

- Only discharged, below 5 % State of Charge, ~~and electrically shortened spare~~ accumulator cells each having all terminals electrically isolated may be presented.

Intent

Prevent unsafe handling and state of cells in design event.



Most important rules changes

EV 8 TSAC Hand Cart

- The firewall must be made from a rigid, fire retardant material, see T1.2.1, and be transparent from 1.3 m above the ground.
- The TSAC(s) must not protrude the hand cart.

Intent

Protect hand cart operator in case of fire.
Ensure safe transportation of TSAC.



Isolation Failure

- Good design practices
 - Follow the spacing defined by the rules
 - Avoid contamination on PCBs
 - Follow coating procedure properly

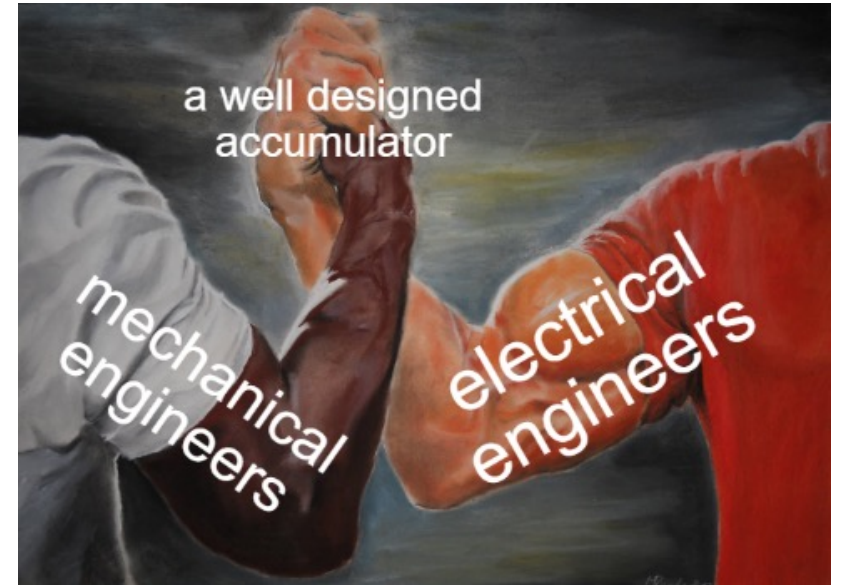
- EV1.2.1

- Isolation test voltage
- Working voltage
→ Rule changed!




Insulation System		Reinforced Insulation
Working Voltage (rated)		1'000 VAC
Isolation Test Voltage	- Input to Output, 60 s	6'000 VDC
	- Input to Output, 1 s	8'000 VDC
Isolation Resistance	- Input to Output, 500 VDC	10'000 MΩ min.
Isolation Capacitance	- Input to Output, 100 kHz, 1 V	20 pF typ.
		30 pF max.
Leakage Current	- Touch Current	2 µA max.

Accumulator Design → Interdisciplinary task

- Main task is mechanical design & well integration of electronics.
 - Communication between electrics, mechatronics and mechanic is key!
- Main review of TS Accumulator is the SES.
 - Make sure your SES responsible is here and/or listening!



Choice of cell format*

	Pouch cells 	Prismatic cells 	Cylindrical cells 
Power Density	+	+	++
Energy Density	++	+	+
Safety	-	0	+
Battery Packaging	+	++	0
Mechanical Stability	-	+	++

If you decide for pouch cells, beware of the - in general - more difficult engineering task.

You may save precious time in design, manufacturing and inspection not using pouch cells!

*Cell chemistry plays as well an important role in the mentioned characteristics

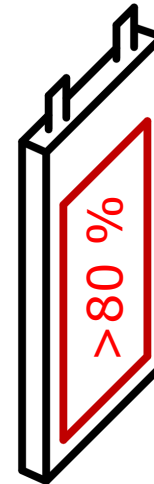
General advice on pouch cells



- Avoid many cells mechanically in series
- No sharp edges, force on large surface
- Do not remove adhesive from cells once applied

General advice on pouch cells

- No loading of cell tabs by PCB
- How much force can be applied to a cell?
 - In general, a lot if evenly distributed over a large surface
 - Material to take loads from swelling is advised



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Calculations

- Analytical calculations mandatory
- FEM may support, if correctly applied
 - show at least:
 - Mesh (sufficiently refined)
 - Force setup, contact modelling
 - Results/failure modes
 - Reasonable division of models
 - Avoid large models with sophisticated contact modelling



















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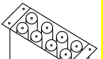

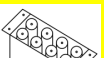

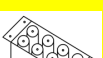

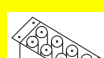


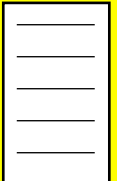

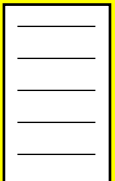

Documentation

- Describe & calculate the whole load path: Frame → Cell

By force direction

By structure/interface

	x	y	z
 	 	 	 
 	 	 	 

	x	y	z
 	 	 	 
Tests and supporting data			
			 

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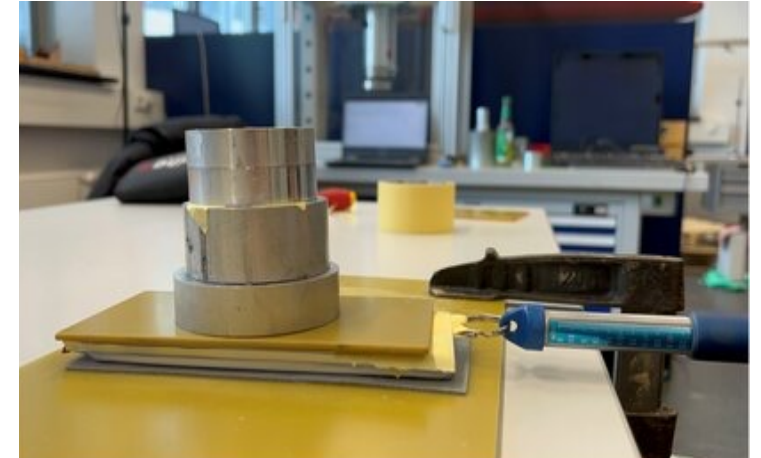
Mechanical properties of non-metallic materials

- Must be valid for ≥ 60 °C !
 - Values from Datasheet
 - Must explicitly show mechanical properties at or above 60 °C.
 - Glass transition temperature alone is **not sufficient**.
 - Values from own tests
 - Test procedure shows mechanical properties ≥ 60 °C.
 - Must be well documented (report, pictures).
 - Scientific justification
 - Generous knock-down factor applied to ambient temperature values.
 - Backed up by known behavior of the explicit material, must be explained.

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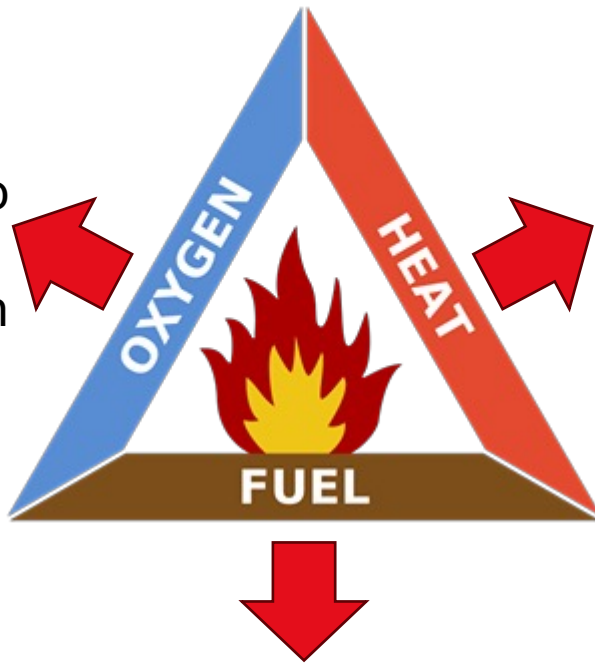
Design of friction-based systems

- Calculate worst-case area of friction.
- Use a design, where you can adjust pre-tension.
- Testing of friction coefficient
 - Cell Mockups are acceptable if representative surface, area and stiffness.
 - Use representative testing pressure.
 - Friction coefficient may be non-linear!
 - Conduct a testing series.
 - The average value may not be the best choice.
 - Document every step with pictures.
 - See guidance notes (in 2024 SES template).



General safety advice/work safety – Battery fire can not easily be stopped

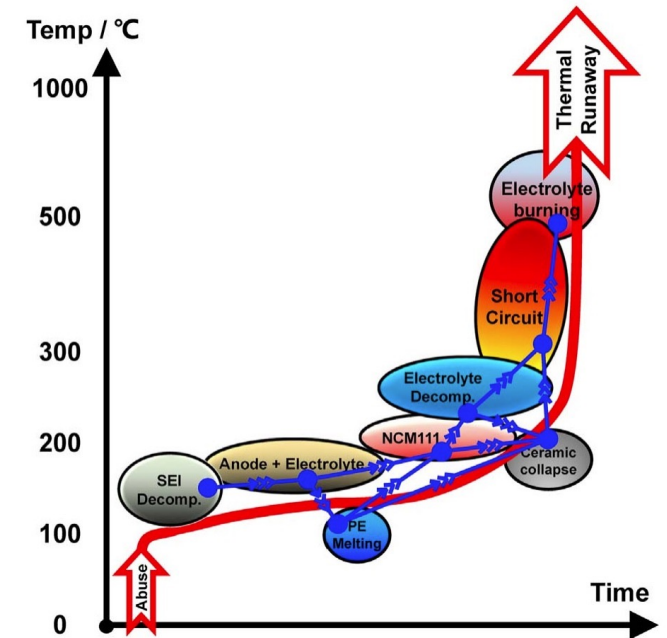
At $\sim 140^{\circ}\text{C}$ the cathode starts to disintegrate releasing oxygen



Electrolyte can act as a fuel

At $\sim 100^{\circ}\text{C}$ the battery cells start self-heating and it can release a huge amount of heat in case of fire

X. Feng et al.



If a cell starts self-heating without reason, evacuate the area and inform the firefighters. You won't be able to stop it from a thermal runaway.

General safety advice/work safety

- Check your safety equipment
 - Correct fire extinguisher (Suggestion: A Class)
 - Fire blanket
 - (Protective) clothing and equipment
- Check the state of your batteries
 - Capacity (SOH), DCIR (SOHR) and temperature are good indicators of the cell health
 - Dispose in time



General safety advice/work safety

- Be prepared for the worst
 - What can and should I do in emergency?
 - Identify emergency routes
 - Position accumulator (cart) accordingly
- Only work on the accumulator in the designated areas on the event site
 - Zero tolerance policy



Worst case: 2016

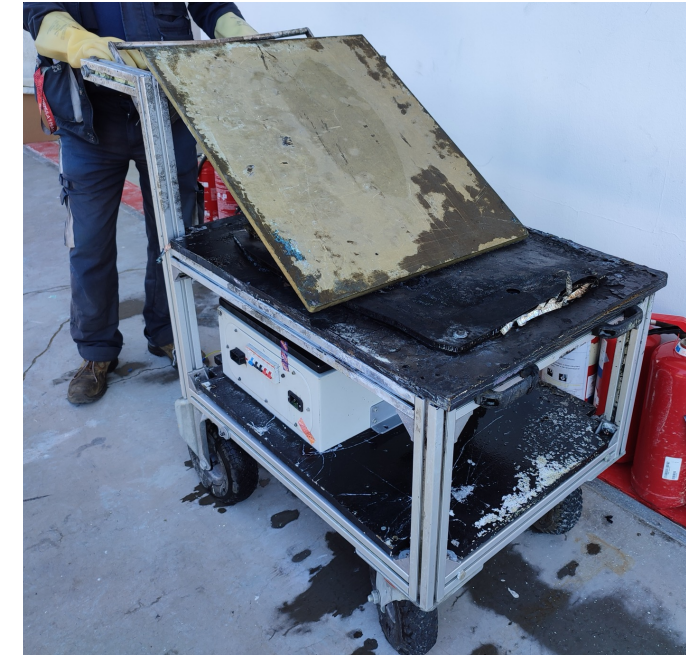


In case of (battery) fire

- Several incidents the past year
 - Stay calm and alert the fire department
 - Nothing is worth personal injury
 - Risk of explosion and toxic fumes
 - Stay away! Do not get closer to take pictures!
- (Hand cart) fire extinguishers will not be able to stop the fire



Worst case: 2022



76 Fire Extinguishers used



Thank you for your attention

Any questions?

Submit them via Slido!