FORMULA STUDENT AUSTRIA

# Best Practices for Accumulator and Electrical Scrutineering

(and Rain Test)

FS4A

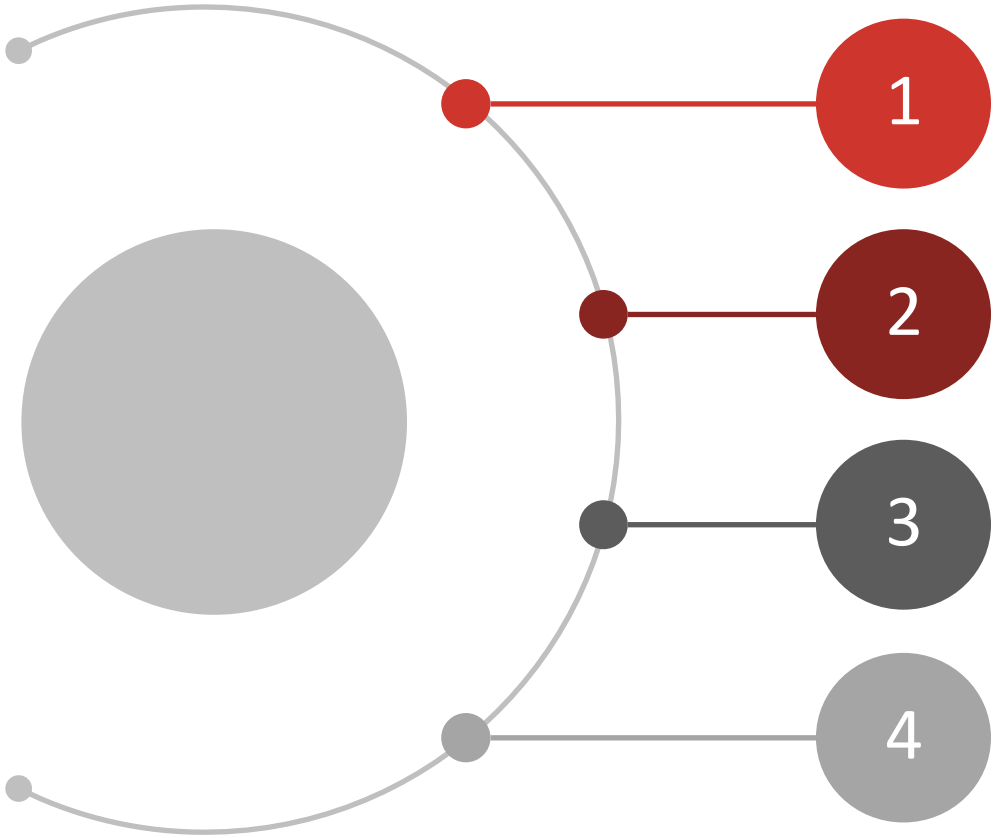
ALPE DRIA FORMULA STUDENT

# Context

- This presentation is ADDITIONAL to the FSG Academy
  FSG Academy 2023: Accumulator
  FSG Academy 2023: EMI
  FSG Academy 2023: Antennas
  (you need to be logged in to the FSG website for access)

- For official Rules Questions, please use the FSG tool
- Don´t forget about the Competition Handbook of each event!

# Overview




1. Tips for Electrical Scrutineering
2. Why are E-Scrutineers so strict?
3. Best Practices for Accumulator Design
4. How to Pass the Rain Test

# Tips for E-Scrutineering – Design Phase

- Read and understand the Rules
- KISS – Keep It Small and Simple
  - The most fancy solution is not always the best solution
  - Easier to Maintain -> Easier to Fix

# Tips for E-Scrutineering – Before the Events

- Know the Inspection Sheet by Heart
  - Do Internal Tech Inspections as soon as possible, also with people outside of your team (Alumni, other Teams, Scrutineers, …)
  - Updated Inspection Sheet is typically online a few weeks before the event
  - Use the old versions in the meantime, see our homepage
- Go to Pre-Events
  - VDE E-Race, VDI Racing-Camp, FS Easter …
  - Try to get a hard scrutineering there
- Test your Car and Fix Your Issues
  - Teething problems, …

# Tips for E-Scrutineering – At the Event

- Have your Stuff together
  - All Datasheets with you
    - Tablet/Laptop need good/full accumulator
  - Bring your Spare parts and PCBs with you to show the scrutineer
  - Bring necessary Tools and equipment
- Have more than one Guy that knows everything
  - Try to split scruties and sheets in two groups
  - One Group start with Datasheets/samples
  - Other Group start with LV measurements

# Tips for E-Scrutineering – Pro Tip

- Always be fully prepared in the pauses between slots
  - If a team does not show up, other teams get the slot for repairs / Re-inspection
  - Be there with your TSC/Car
- Changing of slots is permitted, if both teams agree

# Why are E-Scrutineers so strict

- Voltage above 60VDC is dangerous (theoretically)
- Voltage above 400VDC is REALLY DANGEROUS
- Internal Resistance of LiPO is virtually non-existent
- Burning Accumulators are very hard to extinguish

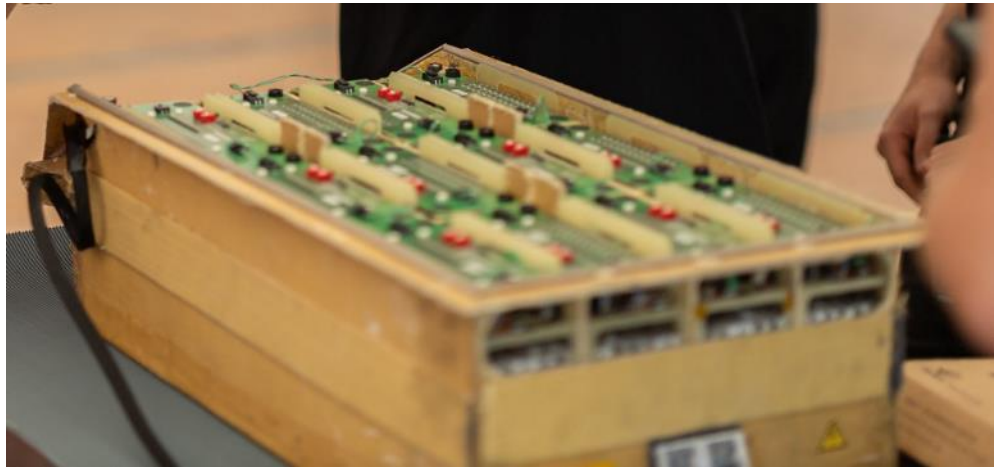
# Best Practices – TS Enclosure Materials

- See EV 3.1.1.
- Additional grounded 0,5mm thick solid aluminium layer necessary for:
  - CFRP laminates
  - Laminates with aluminium honeycomb

→Take the easy route!

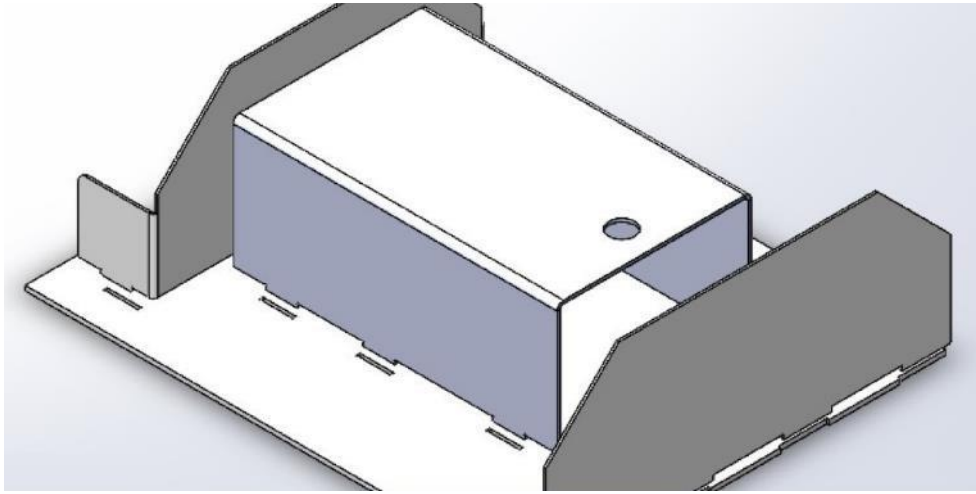
→use ONLY non-conductive materials

→or make it aluminium throughout



# Best Practices – TSAC Mechanical Design

- Laser & water-jet cutters are your friend!
- Design “key - and tongue” features into the bottom and walls
- Also works for laminates:
  - stabilize a foam core with very thin skin
  - then cut & assemble like a wooden box
  - afterwards laminate (wet process)
- Ventilation holes: max. 25% area
- Apply good engineering practice!

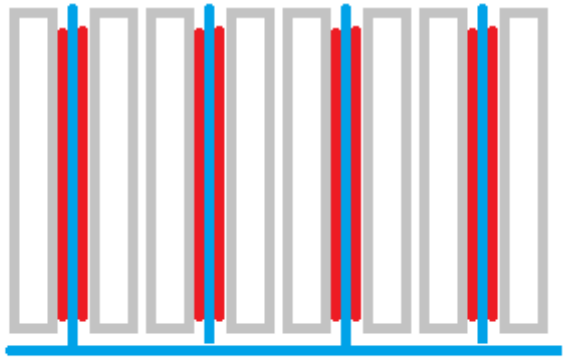


Good for ventilation, but bad for load transfer

# Best Practices – Pouch Cell Attachments

- EV 5.5.9: pouch cells must be fixed using 80% of the large surface area

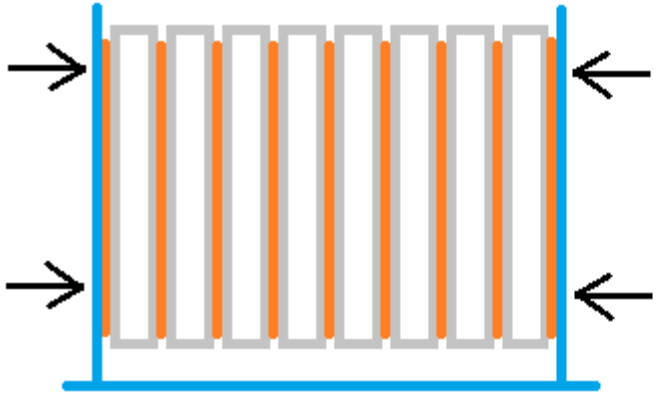
option 1



RED = bonded 80% surface area

BLUE = stack frame

option 2



ORANGE = high friction + compressible material

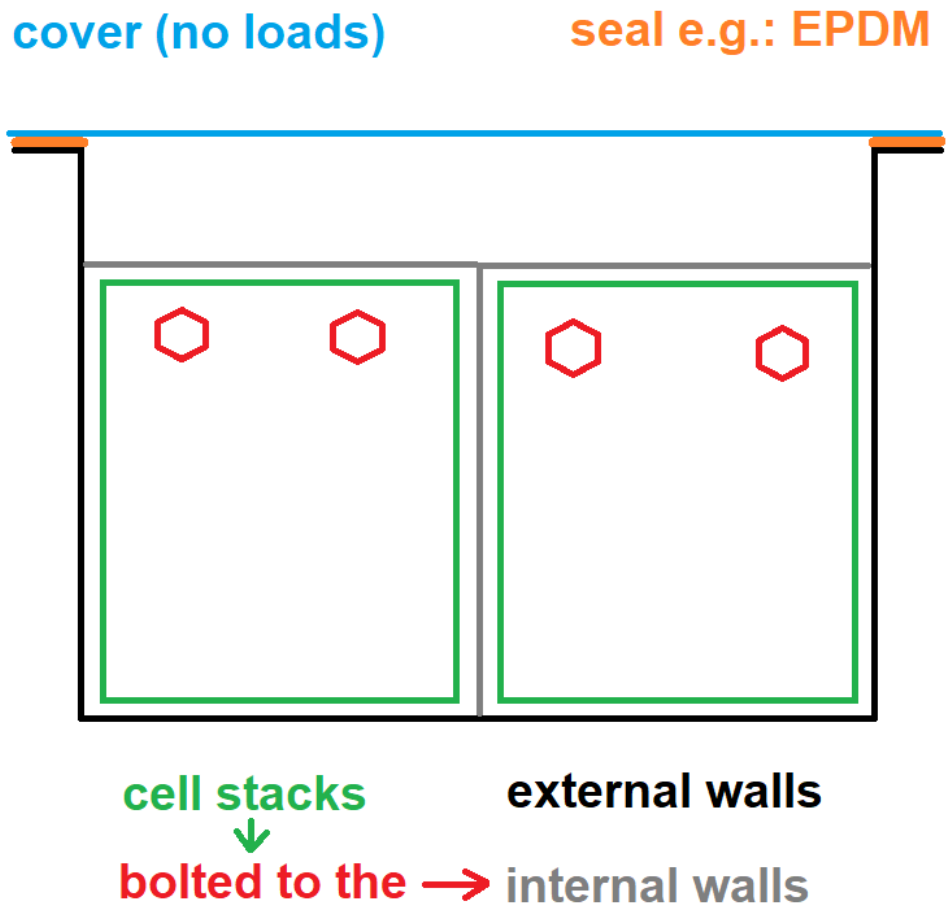
clamping force

# Best Practices – Cylindrical Cell Attachments

- Laser / water-jet cutter  is your friend!
  - Use any type of plate material incl. laminates
  - Better mechanical properties than 3D print
  - Far easier to show fire resistance compared to 3D print because filling grade is always 100%

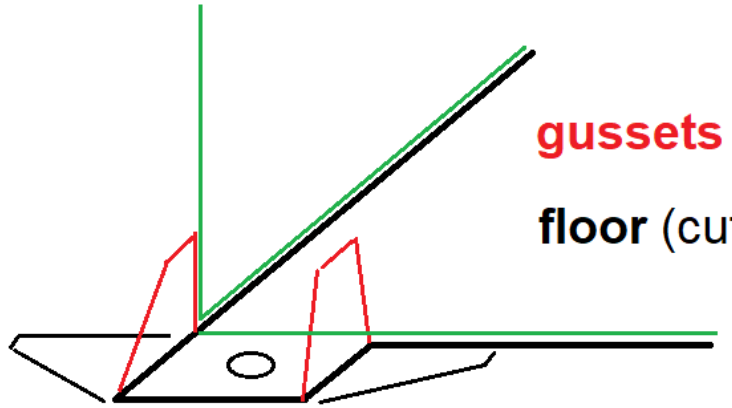
# Best Practices – Stack to TSAC Attachments

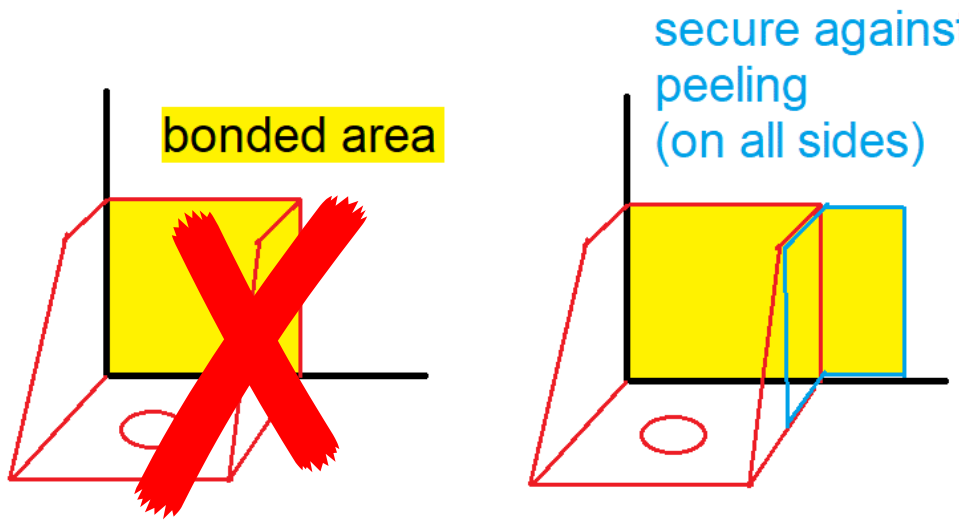
- 40g longitudinal / lateral
  - Direct contact with TSAC walls
- 20g vertical
  - Bottom direction not an issue
  - Upwards direction: don’t use the lid!
- Use the cell stack holding plates bolt them to the internal walls!
- Lid acts as a cover only, no loads
- No need for spacers on top of stacks



# Best Practices –TSAC to Chassis Attachments

- Make brackets integral to TSAC (instead of completely separate part)
- Bonding is acceptable BUT
  - 50% strength reduction (T3.2.8)
  - Adhesion over whole surface is a challenge
  - Must be secured against peeling
- Consider the loadpath – work together with the chassis department!



# Best Practices – Maintenance Plugs

- Good example: Amphenol SurLok Plus
  - Different sockets and plugs
  - Different sizes
  - Finger proof
  - Size might be an issue, but still better than many other solutions

# Best Practices – BMS

- FoxBMS (Open Source)
  - To much stuff, must be tailored
- Build complete BMS from Scratch
  - Applications Notes from NXP and Analog Devices
- Own Open Source Project
  - More than one Team can build BMS together

# Best Practices – Accumulator and Rain Test

- Every Year more than one Team has problems at Rain Test
- IMD Error, often water in Accumulator
  - Accumulator must be disassembled in Accu Tent
  1. Measure Voltage at TS+/- and Housing
  2. Open Container, Open Maintenance Plugs
     1. If you don’t have a good concept here you are lost
  3. Measure each Stack, remove Stacks
  4. Dry your Housing, dry your Stacks
  5. Rebuild an Seal your Container (better)
  6. Retry Rain Test

# How To Pass Rain Test – What awaits you

- [IN 9.2.6] Water will be sprayed at the vehicle from any possible direction. The water spray is similar to a vehicle driving in rain and not a direct high-pressure stream of water.
  - Till 2022 Pressure was some years to high at Rain Test in FSA
  - Since 2023 a Pressure regulator is mounted at FSA Rain Test
- In FSA one Sprinkler is above the car, one Sprinkler is behind the Car
  - Design your chassis to can withstand rain from above
  - Design your TSC cooling to not suck AIR direct behind the car
  - Seal your accumulator additional to the Car

# How To Pass Rain Test – Don’ts

- [IN 9.2.1] The vehicle must be in ready-to-race condition. All components and constructions used to protect the vehicle from water during the rain test must be used during the entire competition.
  - Keep at designing of your car in mind, that you have to seal it against water
  - Adhesive Tape to make your Car waterproof it will be sealed with stickers
  - Breaking of this seals requires new Rain Test

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# Q&A

## Session 3
## Electrical Design & Scrutineering

# Q&A for Electrical Design | 1

| Question | Answer |
|---|---|
| What is the intention of removal of deletion of ICs exception from HV and LV clearance requirement? | There never was a technical reason for this exception, so we deleted it. |
| What are the best ways to ensure water-tight TS enclosures? | 1.) Keep openings to a minimum<br>2.) Take inspiration from OEM solutions<br>3.) Sealed flanges need to stay flat also under load - so require adequate stiffness. A flat cover without any strengthening ribs around the edge will only be pressed firmly at the bolt holes but not in between.<br>4.) Use adequate sealant materials for the job at hand - EPDM for example. Please do not seal your enclosure shut with silicone. |
| Also for batteries where we have seen numerous incidents and ancients happen the past few years, do you think some kind of standardization could improve safety? | Yes, this has been discussed many times. We don't think it makes sense to provide a standardized battery pack or parts thereof. Instead we want to provide you with "best practice" and "how to - guidelines" in order to guide your very own design process into the right directions |
| PCB requirements (traces length, space between HV and LV for isolation), segments configuration for cooling (first battery pack). | Traces should be as short as possible, but as long as they must be. Space between HV and LV is mentioned in the rules. Cooling is normaly simulated with FEM. But if you have cooling issues in your first year you can realy be proud what you achieved. |
| Which insulating materials for internal walls?<br>Are holes allowed in the internal walls for air cooling ? If yes which size and patterns ? | Kapton and Kevlar (Aramid) are the best materials for insulation. If there are holes for cooling, the wall still has to be strong enough to carry the mechanical loads. So long slots are not a good idea (bad load transfer). The 25% of area rules is applied to internal walls as well. The internal wall still needs to be an insulation barrier, so parts of the cell stack near the cooling hole must be insulated. |
| lithium cells: manufacturer only provides vague "maximum current", what sort of peak/pulsed charging/discharging currents are acceptable for the competition? | If you can't get pulse data from the manufacturer you are only allowed the continous rating. Try to contact your manufacturer direct to get a better data sheet. |

# Q&A for Electrical Design | 2

| Question | Answer |
|---|---|
| How can you solve the new requirement for a battery trolley to have a transparent firewall? | 1.) I have personally intervened in order to make sure that the requirement is only there above a certain height limit.<br>2.) Makrolon / Polycarbonate |
| What key parts of the low voltage system do you look at? | See inspection sheet for a good overview. |
| What are some good practices for mechanically separating the TS and LVS cables within a TS enclosures? Have you seen any common mistakes? | Generally any type of cable management works for this. Most commonly of course: zip ties. |
| Can a tab washer be used as a locking mechanism for the AIRs? There were different opinions at the events and we had to change it several times. | Depending on your particular design there might have been issues - we would generally suggest that all-metal locking nuts are the best solution for most cases within the TSAC. In unclear situations during Scrutineering, we try our best to get in touch with Scrutineers from other events in order to make sure, that a solution is accepted there as well - unfortunately this does not always work out. What you can do is bring the inspection sheet of the competition with you to the next event so that the Scrutineer can check for themselves. Be aware that we hear very often "but it was fine at competition XY" so we tend to dismiss such comments. If you have it documented in the Inspection sheet, we will definitely give it much more thought. |
| Is it worth it to manufacture the TSAC out of CFRP or will the mass saving not be worth the additional costs instead of making it out of aluminium? | This depends on your financial, human and material resources! Basically the formula is x*time + y*material + z*money = performance gained, but the x, y and z values will be different for every team in every circumstance. Laminated TSAC is a lot of work in most cases, the time might be better spent optimizing something else or just doing more testing.<br><br>Also: if laminate is a possibility, the solution that makes more sense would be fully insulating materials like aramid fibers + foam core, because with CFRP you would have to include a 0,5mm aluminium layer (EV 3.1.1) and also an insulating layer on the inside. |

# Q&A for Electrical Design | 3

| Question | Answer |
|---|---|
| Does the AMS comply with EV 5.8.3 and EV 5.8.12 rules when it shows only two temperature values: the minimum and maximum? (all other cell temperatures not displayed) | Short answer: no, this is not sufficient. Long answer: see video, Q&A session 3 |
| Can you tell us more about System Critical Signals (SCS)? How should we follow a path, what should we do, etc. | From our point of view, the rules are really clear about this topic - read them carefully and if necessary, please get back to us with a more detailed question in the FSG Rules question tool. |
| Tips and Tricks for an EMI-Concept. | FSG had a whole presentation on this topic in their academy (you need to be logged in to access): https://www.formulastudent.de/fileadmin/user_upload/all/2023/academy/20231021_Schaeffler/08_02_EMI.pdf |
| Mandatory to house the green TSAL driver in the TSAC, or can the existing system be kept, where both green and red TSAL drivers are located on a single board? | The measurment for the TS must be in the TSAC. The rest can be outside. But I recomend it to build it in the TSAC. |
| to battery trolley. there is any consensus to use transparent material to firewall if firewall must be made by 2 material - any UL94-Vo and aluminium. it wont be transparent | The hand cart firewall does not need to include the grounded layer! It just needs to be a rigid and fire resistant material. Also be aware that transparent is only necessary above 1,3 meters! Makrolon (polycarbonate glass) is the consensus for the transparent firewall. |
| EV5.5.6 Is it still needed to add a vertical wall if each segment has its own casing which fulfils all the rule requirements? | Yes, the segments have to be mechanically separated and held in place by internal walls. |
| Can the BMS and low voltage parts of the TSAC be placed above the SIS (in the side view of the vehicle)? | The impact protection structure for the TSAC must be as high as the TSAC itself, with an upper limit of 320mm from the lowest point within the chassis. I guess your question relates to a TSAC that is higher than 320mm, with BMS parts above that 320mm limit. You have to make sure this is still within the rollover protection envelope - apart from that it would be considered okay from my understanding of the rules. Please write a rules question with more details about your design if it remains unclear. |

# Q&A for Electrical Design | 4

| Question | Answer |
|---|---|
| Regarding EV5.5.15: does a plug qualify as an opening which isn't allowed to face towards the driver ? | The intent of the Rule is to not have any "weak spots" in the TSAC facing the driver with regards to mechanical loads and fire. So if your solution is both properly stable and fire resistant, it is okay. |
| you explained that 1 side of the large surface area needs to be sercured although the rules say each large surface. So I understand this as both sides? | See FS Rules version 1.1 : Pouch cells must be fixed using one or both of the large surface(s) only. Each used surface must be fixed on at least 80 %. Tabs of pouch cells must not carry mechanical loads and must not press into the pouch. This should go online in the next days. |
| The panel where the LVMS and TSMS can not be removable. Is it possible to use bolts? | I would fix it with rivets |
| Does the seat need to be conductive/grounded ? | Only the seat mounting points. Also the driver harness mounting points. See EV 3.1.2 |
| Are the ENEPAQ battery cell modules rules compliant? | I think you refer to the modules with 4 (or more) temperature sensors, but only one output to the BMS. As far as I know this is not allowed anymore, but to be sure please write a FSG Rules Question |
| what's the best way to attach the segments to the internal walls with bolts ? (may be a drawing to explain ?) | See drawing in the stream: elongate the cell stack wall (partially) upwards and make a bolt which connects it directly to the internal TSAC wall. You may want to come up with practical solutions so that you can remove this bolt easily while using your safety equipment. You are also not limited to using bolts, the connection can be made with different solutions as well. |
| T11.6.7 It must be possible to separately disconnect each sensor signal wire for technical inspection. - What are the procedures for the technical inspection? | You have to have a connector in your cable loom. It can be at the sensor or you can have a seperate conector at the BSPD. Pro Tip: You can make an adapter PCB for scrutineering, where you connect your cable harness at one side, your BSPD at the other side. At this adapter PCB you can open and short to GND each signal, as the scrutineer want to do. |
| Why aren't Enepaq modules (1s5p configuration=2 sensors between 2-3 and 4-5 cell, d<10mm) rules compliant, if they comply with all the requirements in EV 5.8.4? | Again: please submit a FSG Rules Question with this specific issue. As far as we are concerned, the issue is not the physical number of the temperature readings, but rather that it is not possible the access all temperature readings. So the intent of the rule does not seem to be fulfilled. |