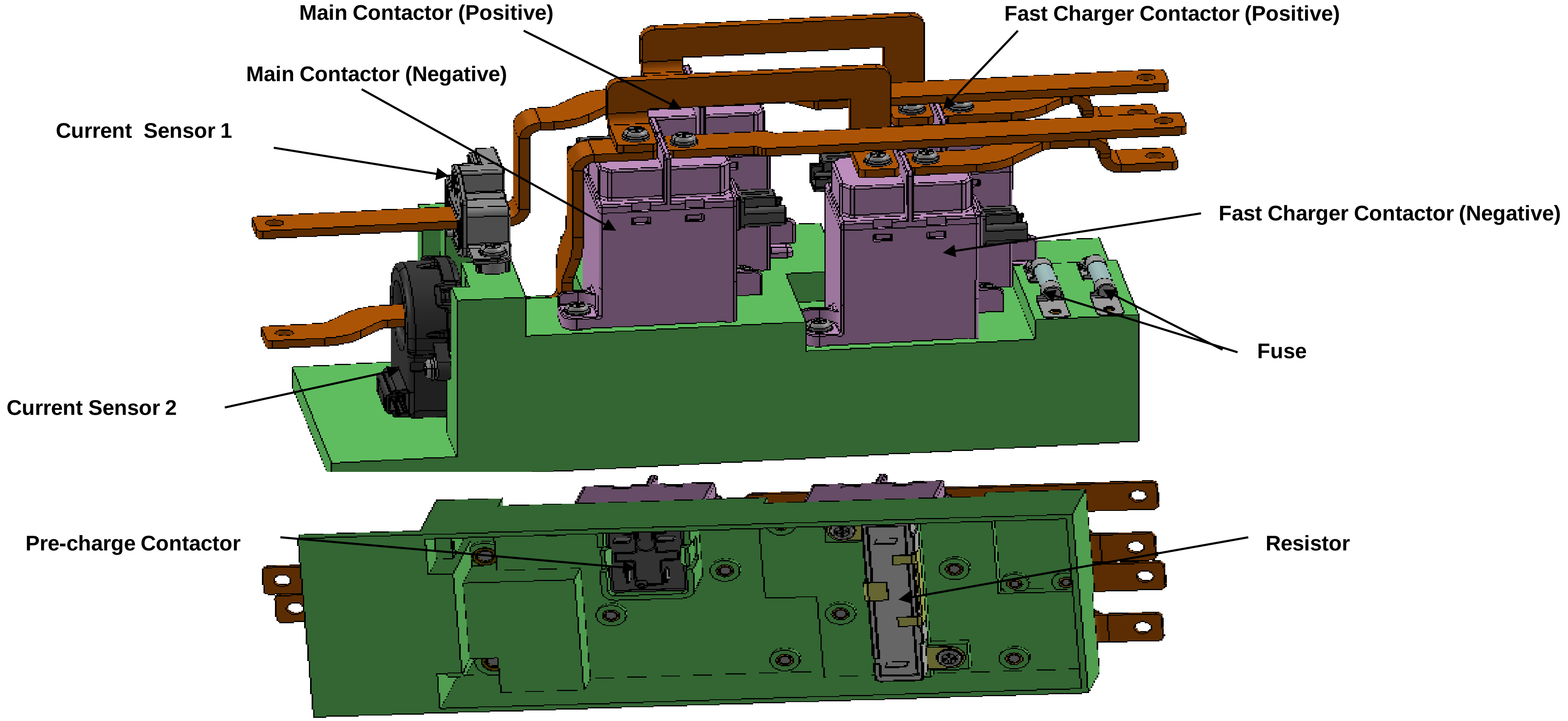
The Battery Disconnect Unit

- A junction box assembly:



Contactor Function

- Contactors connect and disconnect the HV battery to the DC HV Bus (often called the Link), under normal operating conditions.

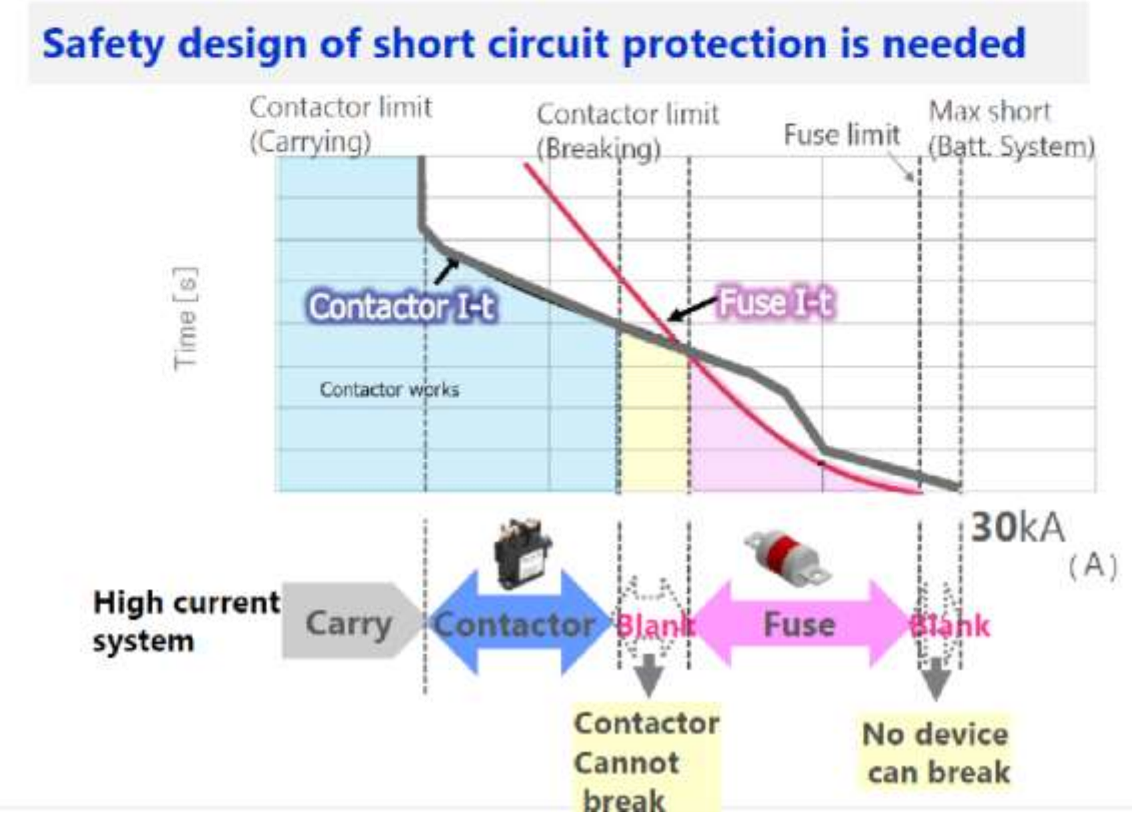
- Contactors are expected to ride through an electrically abusive event (stay closed), and allow the associated fuse to activate.
  - The contactor is not necessarily expected to be fully functional after the event.

- The contactors must be sized for adequate voltage tolerance, per HV systems standards.

- Under normal operation the contactors must be able to handle the following currents over the full design life of the system:
  - Full DC RMS operating current (unlimited time).
  - Continuous current for top speed and fast charge (30 minutes).
  - Peak discharge and charge currents (1 & 10s).

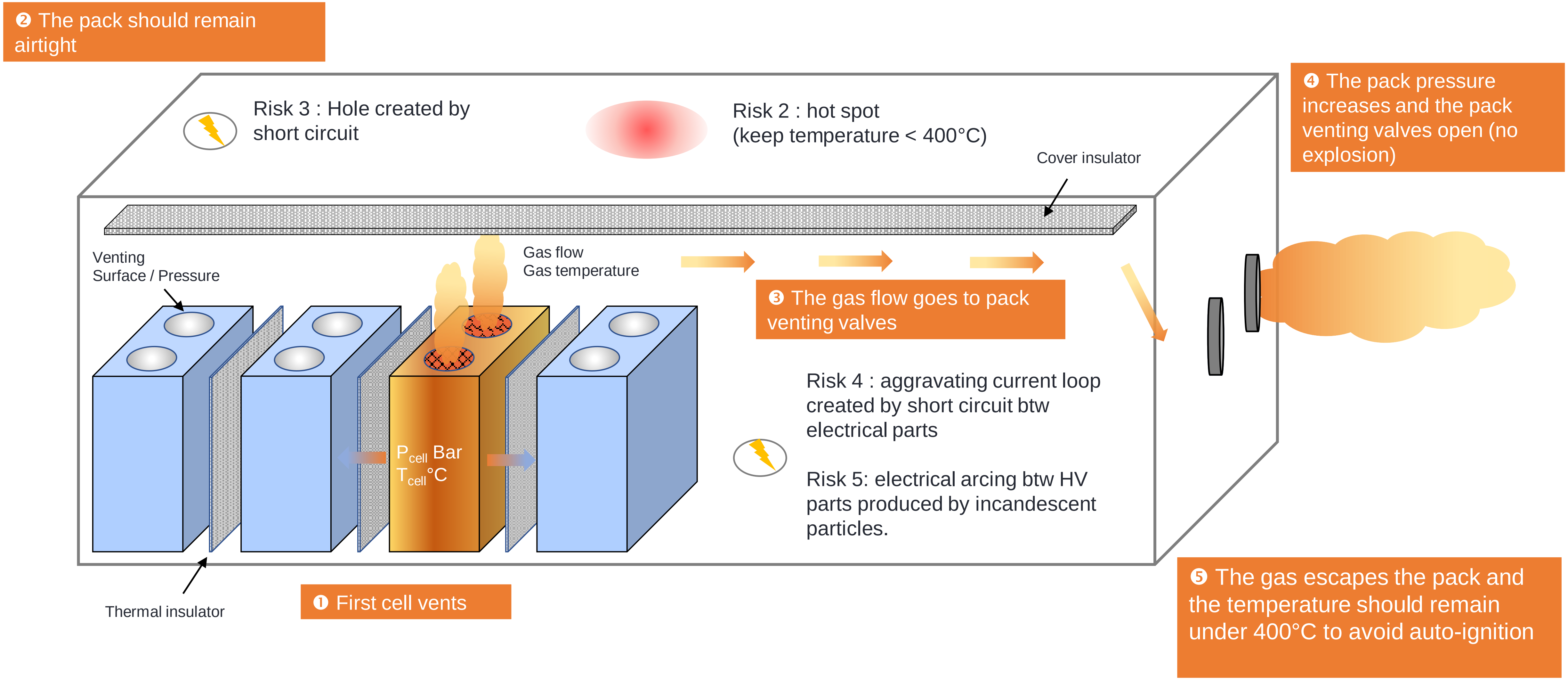
Fuse Sizing

- A battery will contain a main fuse, which is intended to break the main circuit, in the event of a two-point isolation failure, inside the pack.
- Between the BDU and the PIM, an additional (driveline) fuse may be desired, in order to ensure HV protection at the battery HV connector.
- The fuse rating must be selected so it will survive the total useful life of the battery and activate at a level below where the battery cells will be damaged.



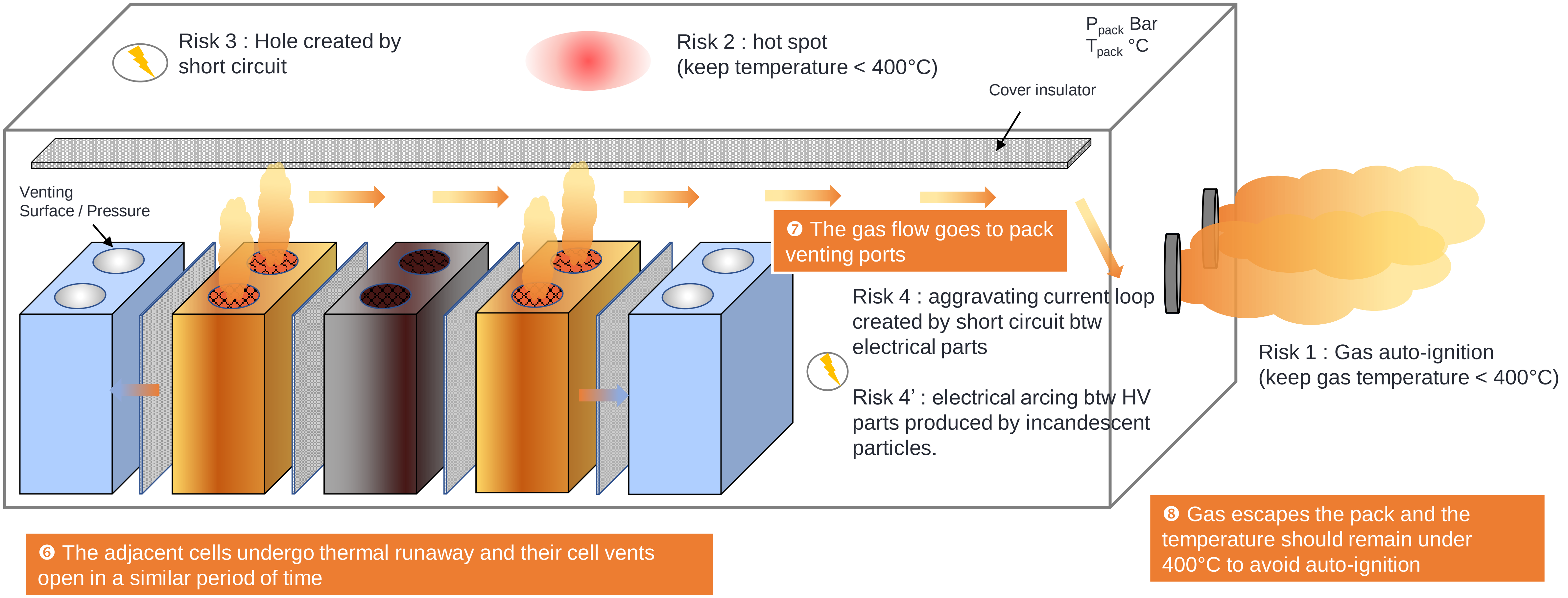
First cell venting :

- This safety concept is based on gas flow management inside an airtight pack : pack pressure increases (due to cell thermal runaway) and is released only through pack venting valves. No explosion, no fire before a required duration time.
- Two main risks have to be covered : Hot gas temperature & electrical short circuits/arcing.

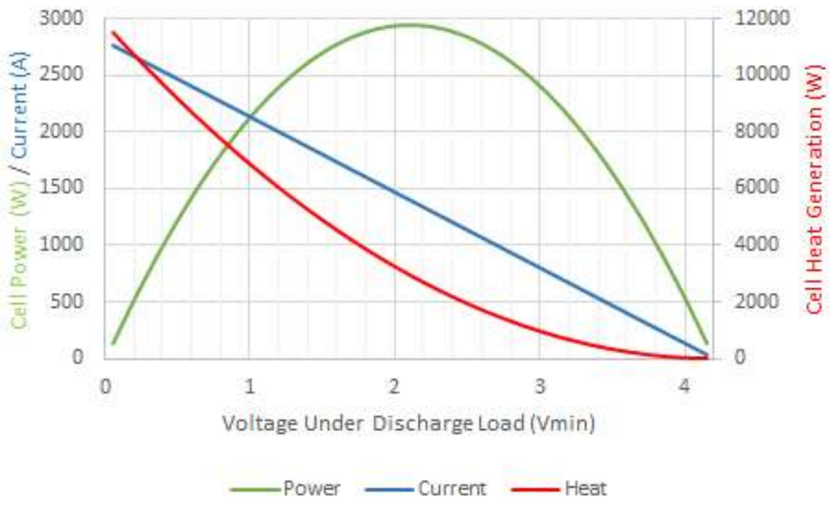


- **Cells with high energy density allow higher vehicle range but are more sensitive/reactive to thermal runaway, increasing thermal propagation risk** :
    - LFP (450Wh/l) < NCM622 (540Wh/l) < NCM811 (620Wh/l)
- **A bigger cell size will generate higher quantity of gas** to be managed : Gas volume = f(cell capacity)
- **Some counter-measures are available but to the detriment of weight, volume, range and vehicle cost**.
- **Regulatory constraints** will need to be accommodated in coming years : **Increased duration** before any user hazard, thermal propagation test **in parking mode** for example.

Propagation to neighbor cells :



- Assume a 60Ah cell. It is LFP/C chemistry, so has a nominal voltage of 3.25V, and operates between 3.7V and 2.5V. Assume it has a nominal discharge resistance of 1mohm and has a specific energy of 160Wh/kg.
- Determine the maximum power this cell can deliver, if fully charged.



1. We assume P_{max} is at $V_{max}/2$; V_{max} = 3.7V, so P_{max} @ 3.7/2=1.85V = V_{load}
2. $P_{cell} = V_{load} \times (V_{max}-V_{load})/R_{cell}$ = 1.85 x (3.7-1.85)/(1mohm/1000mohm/ohm) = 3,423W or 3.42kW

- Compare this to a NMC/C cell, that operates between 4.2V and 2.8V:

1. V_{load} = 4.2/2 = 2.1V
2. P_{cell} = 2.1 x (4.2-2.1)/(1/1000) = 4,410W or 4.41kW

- What would the equivalent C-rate be, for the LFP/C cell?

1. I = P/V = 3,423W/2.1V = 1,630A
2. 1,630A/60Ah = 27C

- How much heat would be generated by the cell?

1. $P_{heat} = I^2 \times R = (1{,}630A)^2 \times 1mohm/1000mohm/ohm = 2{,}657W = 2.7kW$

- If the cell was to discharge at the rate shown how heat energy would be generated?

1. 60Ah/1,630A = 0.37h = 133s
2. 2.7kW x 133s = 358kJ

- What would be the adiabatic temperature rise, if the cell had a specific heat capacity of 1.5kJ/kg*K?

1. Cell weight is 60Ah x 3.25V/160Wh/kg = 1.22kg
2. Temperature rise = 358kJ/(1.5kJ/kg*K x 1.22kg) = 196K (or °C)

- What do you suspect would be the cell failure mode?

1. Separator melt, electrolyte flashpoint, and possible phosphate decomposition.

- If the anode were to react and combust how much energy could it produce in this cell?

1. 60Ah x 3.25V = 195Wh x 3600J/Wh = 702kJ
2. 702kJ/4.9kJ/g for Li_6C = 143g anode
3. 63.6kJ/g anode combustion x 143g = 9,095kJ combustion energy

- Why would this be unlikely to happen in this particular cell?

1. The chemistry is LFP/C, and oxygen is not liberated by the cathode, so this particular reaction will not happen.

- If we would want to prevent the initial cell to go into thermal runaway what is the safe temperature threshold you think should be maintained?

1. Looking at the reactions temperature table: 85°C to 130°C.

- Assume the cell is a prismatic can 220mm wide x 102mm high x 22mm thick, not accounting for terminals, what would the bulk heat transfer coefficient (W/m^2*K)need to be to hold this temperature?

1. Use 130°C for this case. Assume 25°C ambient = 105°C Trise.
2. Area of cell is 220 x 102 x 2 + 102x22 x 2 + 220x22 x2 = 193,511mm^2 or 0.194m^2
3. 2.7kW heat generation, so HTC = 2700W/(0.194m2 x 105K) = 133W/m^2*K

- Calculate the minimum DC isolation resistance for a 76V system. For a 920V system.

1. (76V+1000V) x 500ohm/V = 538kohm
2. (920V + 1000V) x 500ohm/V = 960kohm

- A thermal fuse is used to prevent excessive currents from leading to thermal events within the high-power systems.
- Use the fuse table to determine what minimum amperage rating should be used to protect the cell from a 2s maximum power short.

1. 1,630A is a 200A rated fuse.