

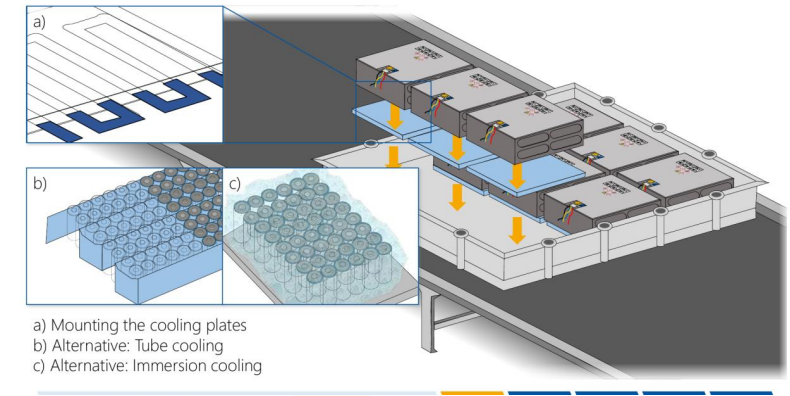
EV / HEV MANUFACTURING · BATTERY PRODUCTION

Production of Battery Modules & Battery Packs

Key concepts of the module and pack assembly process chain

Adapted from the guide by **PEM RWTH Aachen University & VDMA** (4th ed., 2023)

Bachelor in Sustainable Transport



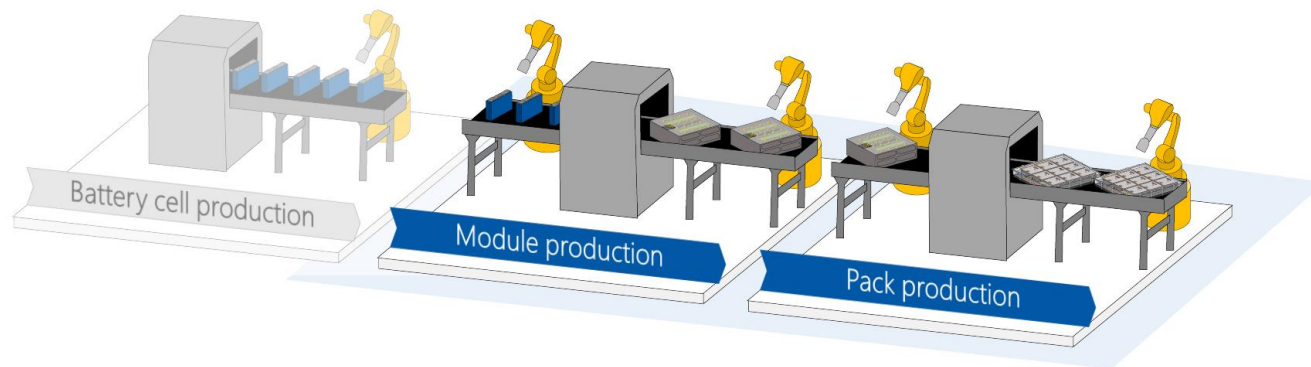
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Sustainable Transportation within the Framework of Green Deal - SPHERE

Call: ERASMUS-EDU-2023-CBHE-STRAND-2

Project Number: 101128065

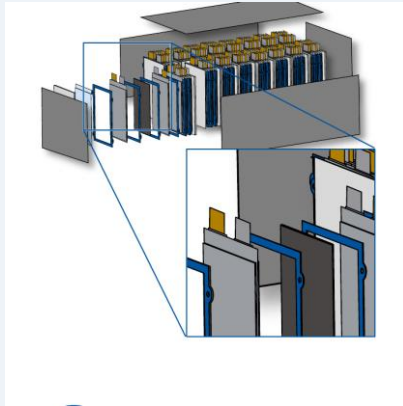
From cell to module to pack



Key concepts

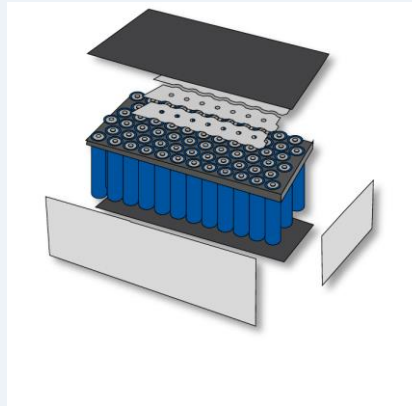
- Battery cells are first joined into modules (in series and/or parallel), then several modules form a pack.
- A module adds a frame, busbars and contacting; a pack adds the BMS, cooling, high-voltage distribution and a housing.
- Module and pack assembly is increasingly produced in-house by OEMs.
- This guide covers the full module → pack process chain.

Module designs by cell format



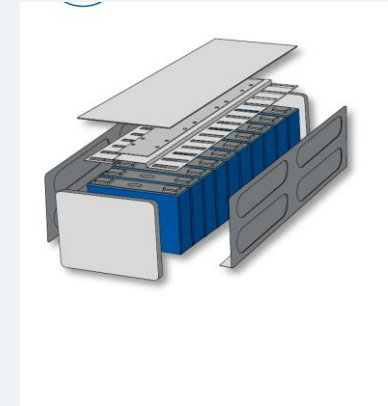
Pouch-cell module

Cells stacked & interconnected; gap fillers and cooling between cells; design must allow for cell “breathing”.



Cylindrical-cell module

Round cells held in carriers, contacted by busbars; wave-shaped cooling; rugged, standardized, low cost.



Prismatic-cell module

Cells stacked with no gaps, bonded by adhesive films; fillers give thermal, vibration and swelling control.

Pack architectures & future trends

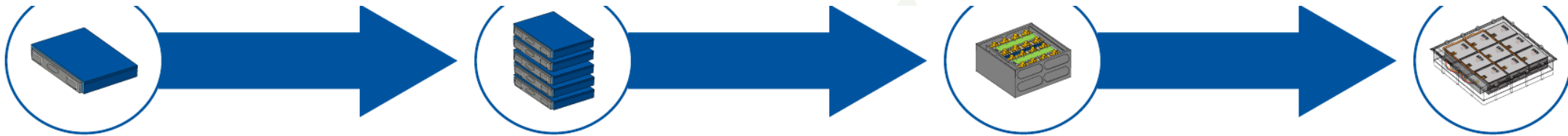
Source: Helmholtz Institut Ulm Geladen podcast (Cell-to-Pack vs. Cell-to-Chassis) 2022



From modules to cell-to-pack

- Cell-to-Module-to-Pack (CtM-P): the classic, modular architecture — easy to service but more parts and mass.
- Cell-to-Pack (CtP): the module level is skipped, cells go straight into the pack — fewer parts, higher energy density.
- Cell-to-Chassis (CtC): cells integrated into the vehicle structure — highest density, greatest complexity.
- Trend: integrative designs that cut components and raise energy density.

Three segments of the assembly line



Cell-to-Stack

Cells are joined into a cell stack/cluster. High batch size, short process times.

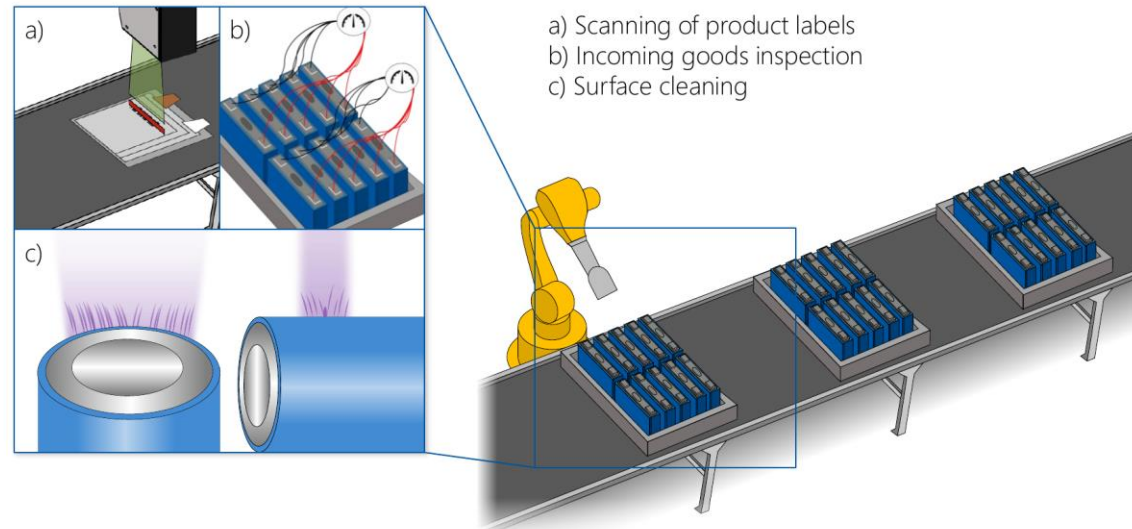
Stack-to-Module

Stacks are built into modules. Batch size tapers; the high-voltage area begins after contacting.

Module-to-Pack

Modules are integrated into the pack. Smallest batch size, extensive testing, longest process times.

Begin-of-line testing



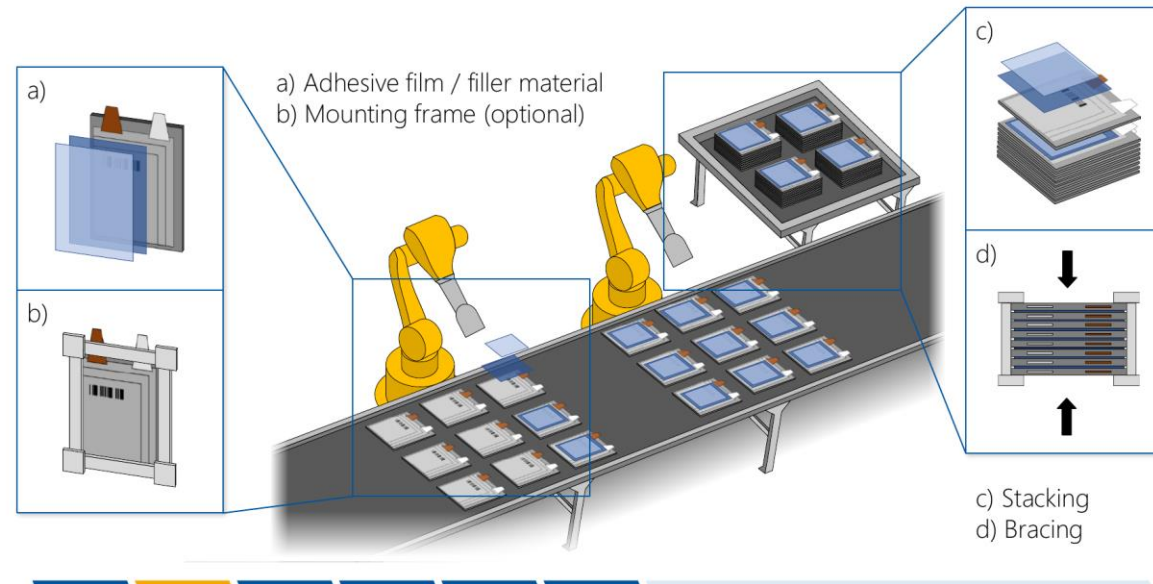
Process

- Delivered cells are placed on the conveyor and their labels scanned (cell model, DMC).
- Incoming inspection sorts out defective cells (OCV, capacity, internal resistance, impedance).

Quality & traceability

- Cells are graded and grouped so every module is balanced in capacity.
- Surfaces are cleaned/activated (laser, plasma, CO₂ snow-jet) for later bonding.

Stacking the cells



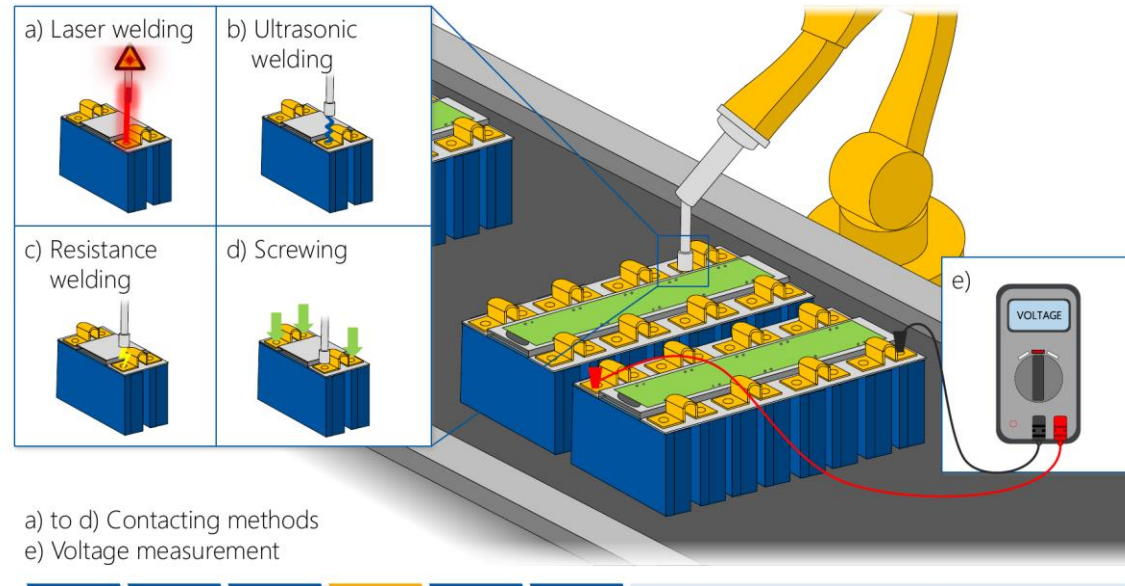
Process

- Cell tabs are pre-bent; adhesive film and thermal filler are applied to the cleaned cells.
- Cells are stacked (cell-to-stack) on stacking tables with a defined geometry.

Key points

- Optional frames/holders set cell spacing and protect pouch cells.
- The stack is finally tensioned to a defined surface pressure to limit swelling.

Contacting the tabs (cell interconnection)



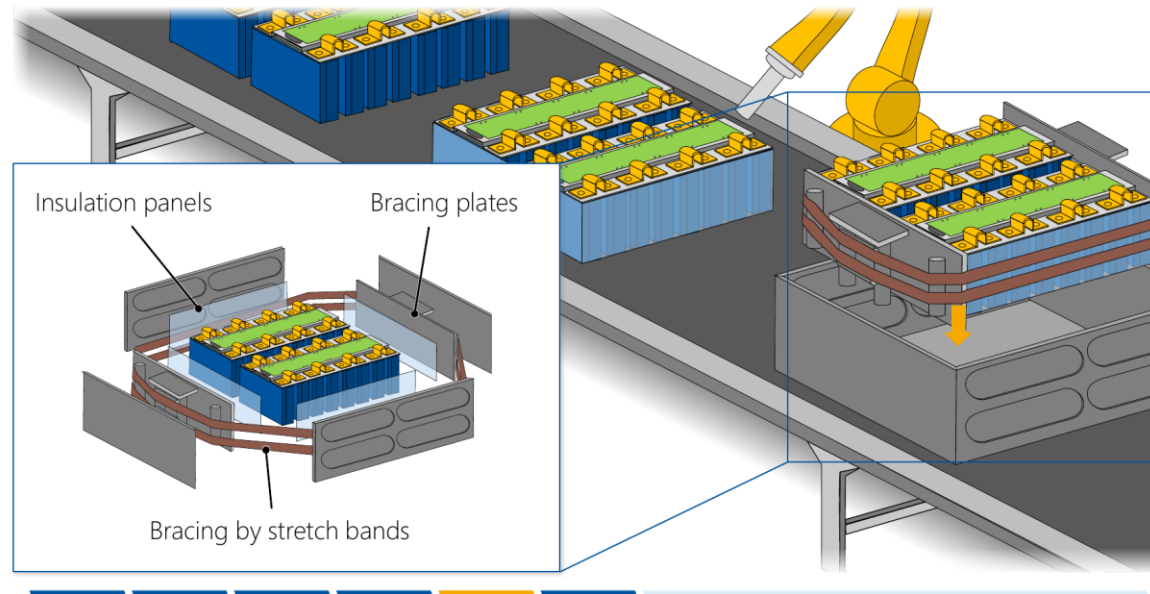
Process

- Busbars are positioned and the cells are wired in series/parallel to reach the module voltage and capacity.
- Joints are made and then checked (e.g. resistance measurement, optical weld-seam inspection).

Joining methods

- Laser welding — flexible, short cycle times
- Ultrasonic welding — low heat input
- Resistance welding — high automation
- Wire bonding — acts as cell-level fuse

Tensioning & module final assembly



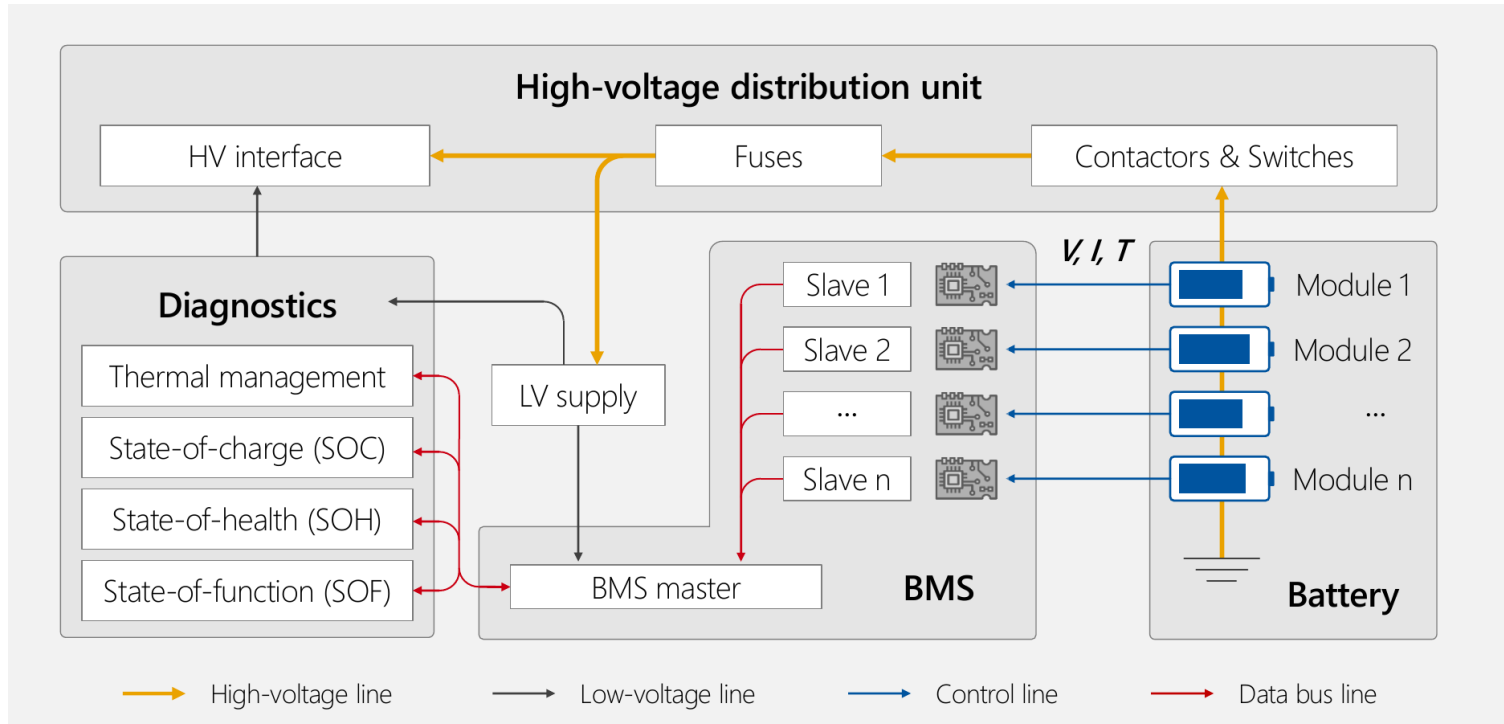
Tensioning

- The cell stack is clamped/braced and fixed in the module housing with insulation and TIM.
- Fire-protection or thermal pads can be added to slow heat/fire propagation.

Final assembly

- Wire harnesses and the cover plate are fitted; the module is sealed.
- End-of-line test: dimensions, communication/sensors, tightness — then labelling.

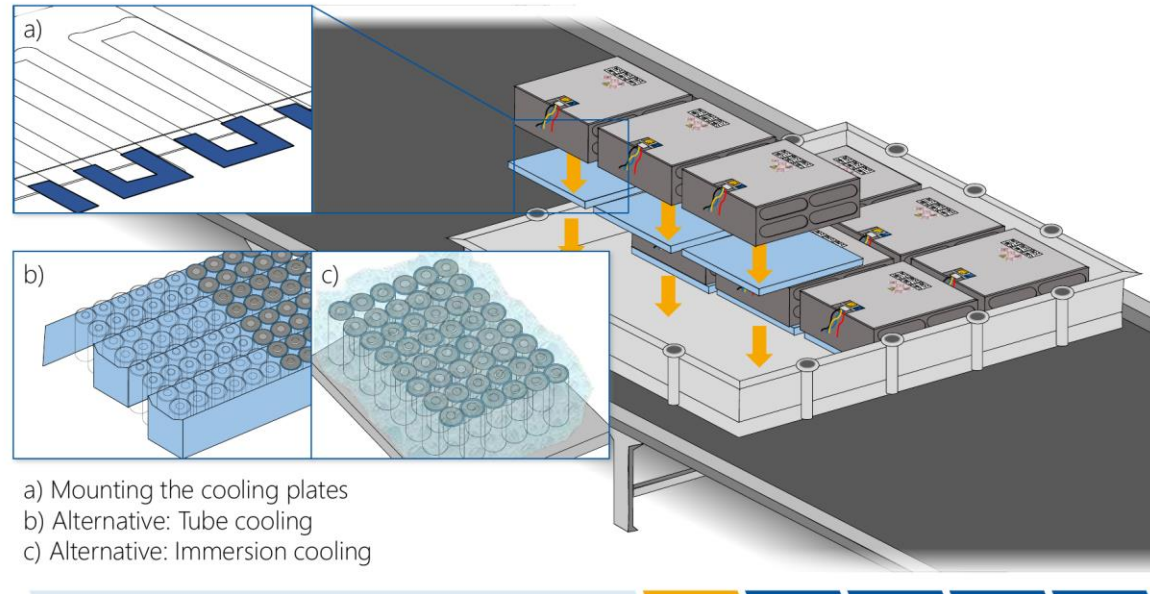
The Battery Management System (BMS)



The “brain” of the pack

- A master at pack level plus slave boards at module level monitor voltage, current and temperature.
- It estimates state-of-charge (SOC), state-of-health (SOH) and state-of-function (SOF).
- It balances cells, maximizes efficiency and triggers HV safety actions on a fault.
- Trend: decentralized and wireless BMS, networked with the vehicle.

Mounting the modules & cooling



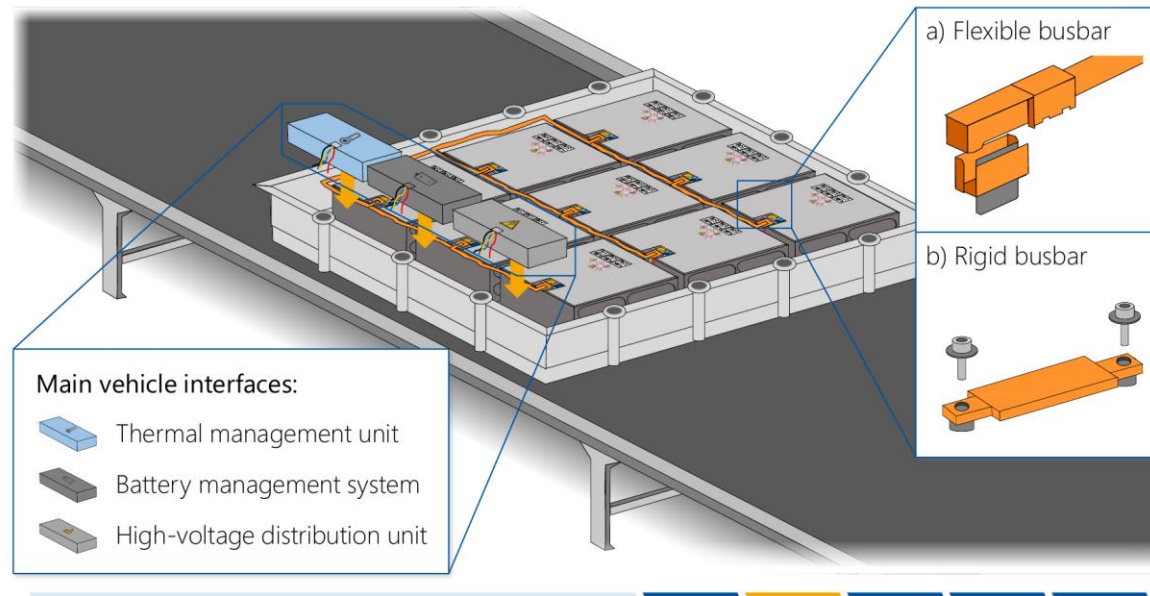
Process

- A centralized/decentralized cooling system is fitted, then modules are inserted by grippers (EOAT).
- Modules are fixed by screws or adhesive; safety components (crash structure, fusing) are added.

Thermal & wiring

- Cooling options: base plate, intermediate cooling plates, hose cooling, immersion cooling.
- Wiring varies by application (e.g. 4S3P, 6S3P; S = series, P = parallel).

Internal components, sealing & leak test



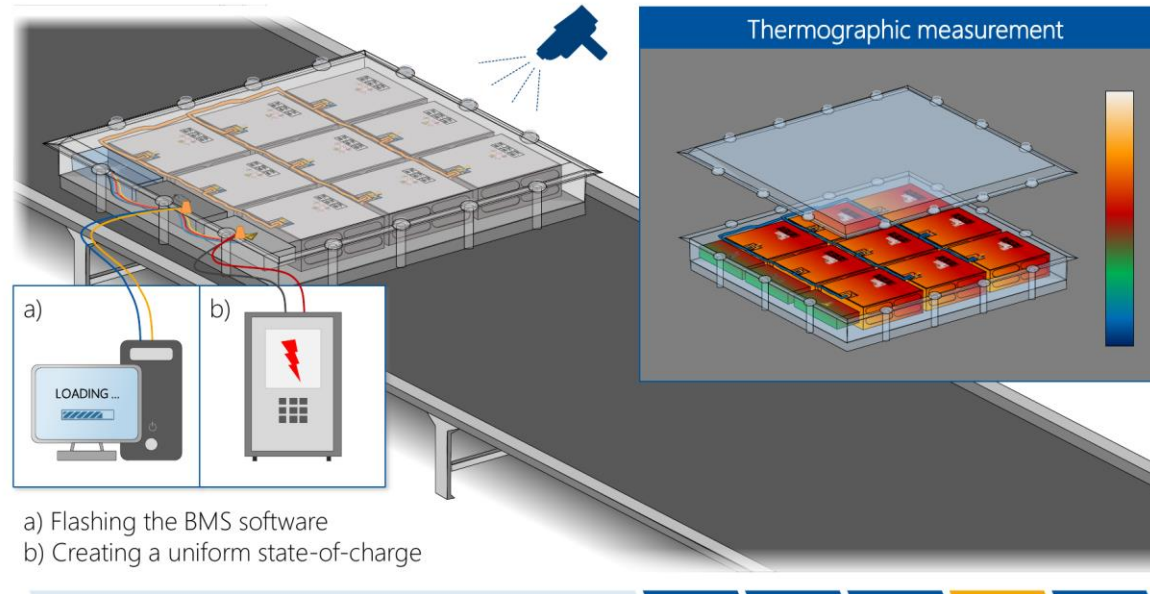
Internal assembly

- The thermal-management unit, HV distribution unit (relays, fuses, pre-charge) and BMS master are fitted.
- Modules are interconnected with flexible/rigid busbars; insulation via TIM.

Sealing & leak test

- Seals are applied and the housing cover is fastened; a bursting disc secures pressure.
- Leak test of housing and cooling circuit (differential pressure / tracer gas).

Charging, flashing & end-of-line testing



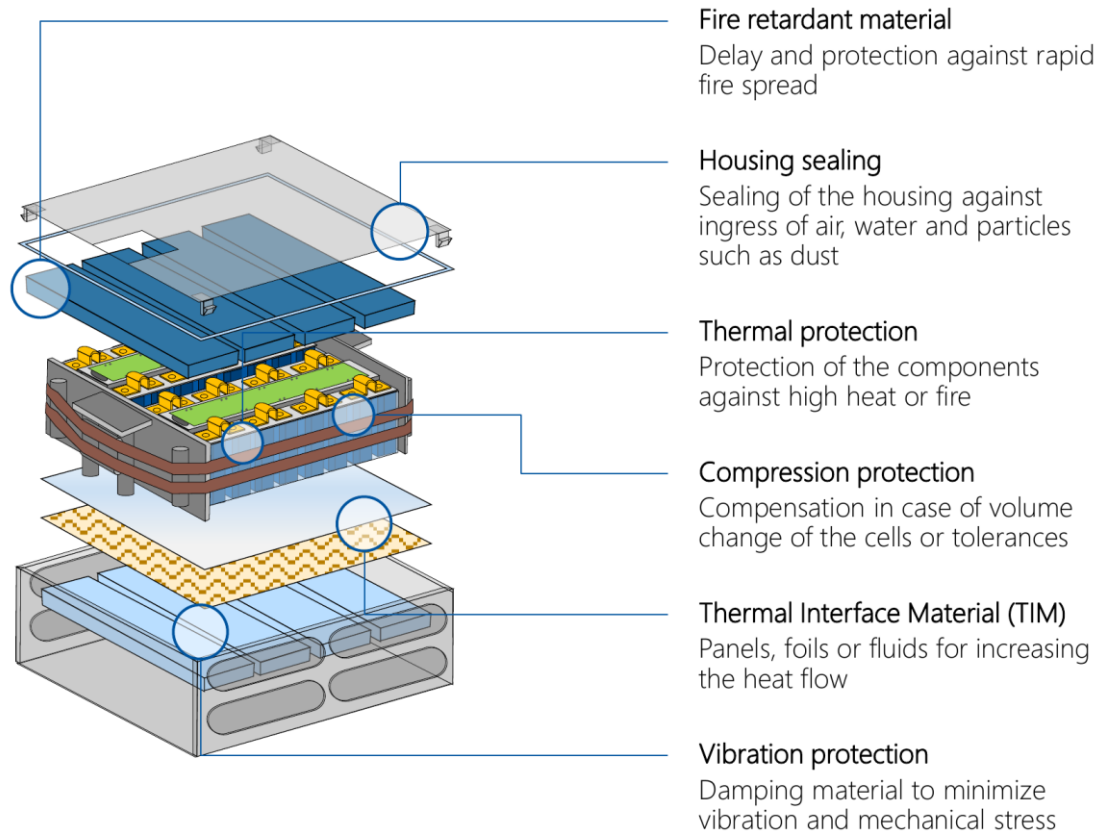
Charging & flashing

- The BMS is flashed with the latest software; all systems are verified.
- A defined, uniform state-of-charge (SOC) is set across the cells.

End-of-line testing

- Thermography can monitor welds and thermal behaviour during charging.
- Final EOL test, labelling as “approved”, then packaging (e.g. Battery Passport).

Hazards & safety in module and pack production



Potential hazards

- Chemical: toxic electrolyte/vent gases; hydrofluoric acid with moisture.
- Thermal/mechanical: thermal runaway, fire and explosion risk.
- Electrical: hazardous HV, short circuits, arc-flash burns.

Safety measures

- Technical: pole caps, light barriers, fire walls, fume extraction.
- Organizational: labelling, safety clearances, emergency procedures.
- Personal: insulated HV tools, HV training, PPE, first aid.

KEY TAKEAWAYS

- 1 **Production runs cell → stack → module → pack, with batch size falling and testing rising along the line.**
- 2 **Module steps: incoming test, stacking, tab contacting (welding), tensioning and final assembly.**
- 3 **Pack steps: module mounting and cooling, internal components and busbars, sealing/leak test, charging/flashing and EOL test.**
- 4 **The BMS, thermal management and safety engineering are decisive for efficiency, range and safe production.**

Reference

PEM of RWTH Aachen University & VDMA (Eds.). *Production Process of Battery Modules and Battery Packs*. 4th ed., Frankfurt am Main, July 2023. ISBN 978-3-947920-45-7. Authors: H. H. Heimes, B. Dorn, D. Neb, H. Clever, A. Scheibe (PEM); S. Michaelis, J. Schütrumpf (VDMA). pem.rwth-aachen.de · vdma.org

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