iONE Core

Battery Module 51.2 V / 314 Ah

Pack · Enclosure · Thermal Management — Integrated Specification

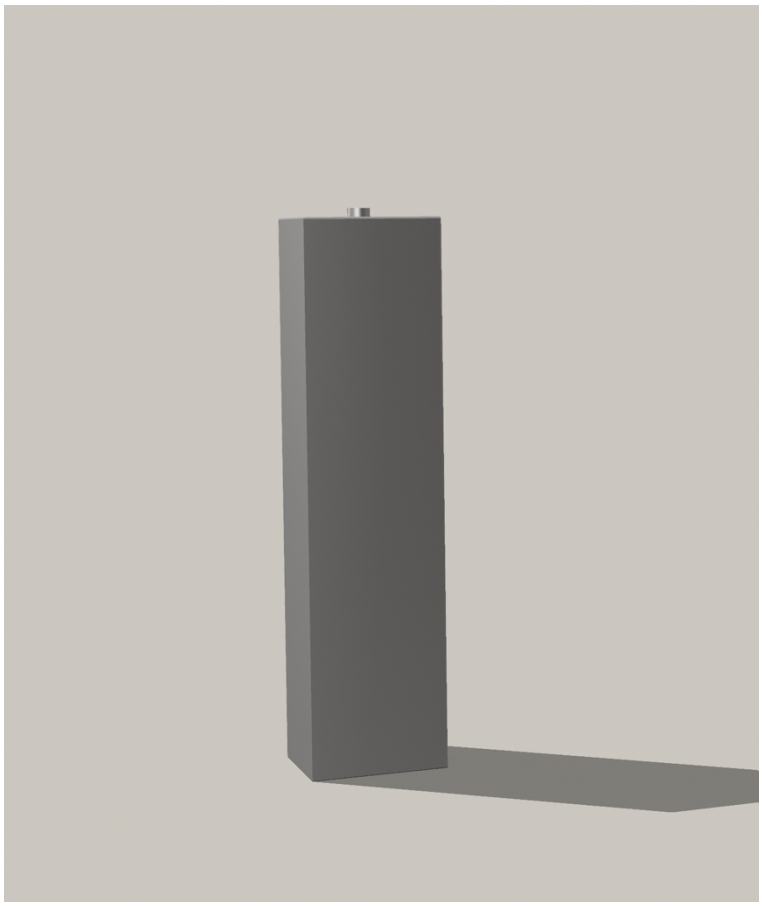
16S LFP · 16 kWh · Active-Balance BMS · CPCM Thermal Buffer · Extruded Al Enclosure

SIGRATHERM ePCM panels · Single-side heater on Al heat-spreader · FIPG-sealed bottom · Silicone cord cover gasket

Certification: CE · IEC 62619 · UN 38.3 · IEC 62133-2 · EU Battery Regulation 2023/1542 (CFP · Passport · Due Diligence)

GT GmbH · Berlin

Document GT-BAT-SPEC-001 · Version 1.3 · 2026-05-17



Document control

Document ID	GT-BAT-SPEC-001
Version	1.3
Date	2026-05-17
Status	Integrated specification — pack, enclosure, thermal management and EU Battery Regulation compliance plan consolidated.
Owner	Ivan Gorb, CEO GT GmbH
Cell variant	XDLE CBA71173204-314Ah (LFP, 314 Ah)
Use case	Standalone outdoor battery cabinet (residential, commercial, industrial ESS)
Audience	Battery assembler · GT engineering · TÜV / notified body · CE technical file · Insurance underwriter · EU 2023/1542 verification body

Reading guide

Each engineering decision is annotated with three lines:

- **CE basis** — EU directives and harmonized standards underlying GT's self-declaration of conformity.
- **TÜV / IEC basis** — international standards against which the module is tested by a notified body.
- **Verification** — how the decision is checked at audit and in production.

Document structure

1. Product overview and architecture

1.1 Product

The iONE Battery Module is a self-contained, standalone outdoor battery cabinet. The product integrates: (a) 16S LFP cell pack of 16 kWh nominal energy, (b) JK active-balance BMS with dual-channel power wiring, (c) industrial-grade protection (Class-T fuse + DC contactor + precharge + rotary disconnect), (d) single-side composite PCM thermal buffer with active heater on Al heat-spreader, (e) asymmetric insulation (silica aerogel + Foamglas with antiabrasive coating), in extruded aluminum enclosure with FIPG-sealed bottom, removable silicone-gasketed top cover, and regulated venting.

1.2 Architecture summary

Form factor	Standalone outdoor cabinet, one pack per enclosure
Mounting	Floor-standing; stackable vertically (transition belt) and laterally (M8 boss-to-boss)
Protection	IP65 (enclosure-level)
Operating environment	Outdoor, −20 … +50 °C, direct sun permitted (white reflective coating)
Use case	Residential ESS, commercial energy storage, telecom backup, off-grid agriculture, C&I storage
Maintenance	Swap-on-site 5–10 min; full repair in GT workshop only
Production volume target	Series-1: 50 units (Q4 2026 / Q1 2027); ramp to 200 units/year
Target BOM cost	€2400–2900 per module

1.3 Thermal architecture — single-side configuration

Thermal management is asymmetric. Active heating and PCM buffering occupy ONE side of the pack (opposite to BMS). Heat distributes through the cell stack via copper busbars (high thermal conductivity). The BMS side uses Foamglas with antiabrasive coating and recessed window for BMS electronics.

Layer order (looking down on pack cross-section, BMS on right):

Enclosure wall (left) — Aerogel 20 mm — CPCM panels ~12 mm — Heater on Al heat-spreader ~3 mm — Cell stack 217 mm — Foamglas 40 mm with BMS window 35 mm — Enclosure wall (right)

Top and bottom of pack: aerogel 20 mm (no heater, no PCM — only insulation).

2. Module specifications

2.1 Electrical parameters

Parameter	Value	Notes
Nominal voltage	51.2 V	16S LFP × 3.2 V
Voltage range	40.0 V – 58.4 V	
Nominal capacity	314 Ah	0.5C, 25 °C
Nominal energy	~16.0 kWh	
Continuous discharge	200 A	BMS-limited; typical use 50–100 A
Peak discharge	350 A for ≤ 5 s	
Fault interruption	20 kA DC at 160 V	Class-T fuse Mersen A3T-300
Continuous charge	25 A default, up to 100 A configurable	
Active balancing	2 A continuous	Energy-transfer
Precharge	47 Ω, 50 W, ≤ 2 s	Vishay RH050 + AHES4291
Main contactor	Gigavac GX14CAB, 200 A continuous, 12 V coil	

CE basis: EU 2014/35/EU LVD — operates below 75 V DC; designed per harmonized safety principles

TÜV / IEC basis: IEC 62619:2022 §6 Electrical type tests · IEC 62619:2022 §8.3 Single-fault tolerance

Verification: Type-test by notified body per IEC 62619 Annex A.

2.2 Thermal operating range

Mode	Cell temperature	Module action
Charge (standard)	+15 … +45 °C	Full-rate
Charge (de-rated)	0 … +15 °C	0.2C–0.3C
Charge (prohibited)	< 0 °C or > +60 °C	BMS blocks; heating activates if cold
Discharge	−20 … +60 °C	Full
Storage	−30 … +60 °C	
BMS electronics	−30 … +70 °C	
CPCM phase change	+25 °C (T_phase)	SIGRATHERM ePCM

2.3 Mechanical parameters

Parameter	Value
Pack envelope (cells + busbars)	≈ 215 × 177 × 1180 mm (W × D × H)
Pack with thermal layers + BMS	≈ 278 × 217 × 1230 mm
Enclosure internal cavity	295 × 245 mm (between walls, minus rails)
Enclosure external	300 × 250 × ≈ 1280 mm
Empty enclosure mass (Al 6063-T5, 2.5 mm)	≈ 18 kg
Pack mass (cells + electronics)	≈ 110–115 kg
Total module mass	≈ 130 kg
Orientation	Vertical only
Transport	Vertical preferred; horizontal allowed ≤ 72 h, vibration ≤ 0.5g RMS
Lifting	Eye-bolts on top cover; floor-standing

2.4 External interfaces

All interfaces on one short end of enclosure (FEM — Front End Module):

Interface	Connector	Function
Power +51.2 V	Amphenol SurLok Plus 8 mm red, IP67, HVIL	Pack positive (post-fuse, post-disconnect, post-contactor)
Power −51.2 V	Amphenol SurLok Plus 8 mm black, IP67, HVIL	Pack negative
RS485	M12 D-coded female panel-mount IP67	Modbus RTU 115200 bit/s
Contactor control	M12 A-coded female panel-mount IP67	12 V coil drive from CE board
Service disconnect	Lockable rotary switch (Schneider VBF or Eaton P3-100)	Manual visible isolation AFTER Class-T fuse
Protective earth	2 × M5 ring on opposite edges, 6 mm² yellow-green	Redundant equipotential bonding
LED status window	Polycarbonate panel on FEM face	BMS LEDs visible

3. Bill of materials

3.1 Pack BOM

Item	Component	Vendor / model	Qty
3.1.1	LFP prismatic cell 314 Ah	XDLE / CBA71173204-314Ah	16
3.1.2	BMS 16S 200 A active balance	JK BMS (Gobel) / JK-PB2A16S20P	1
3.1.3	JK Interface Board (breakout)	JK / JK-CN-Link	1
3.1.4	Aluminum endplates 10 mm, 6082-T6 anodized	Custom	2
3.1.5	Aluminum cage side rails, 6082-T6 anodized	Custom	2–4
3.1.6	Threaded rods M8 grade 8.8, stainless A2	DIN 976	4
3.1.7	Belleville washers M8 DIN 2093 A8 (stacked)	Standard	8–16
3.1.8	Inter-cell buffer pads (silicone foam)	PORON EVExtend or eq (◇ §12.1)	15
3.1.9	Busbars with welded M4 studs	XDLE supplier	15 + 2 power
3.1.10	Aluminum heat-spreader plate 2 mm anodized	Custom 6063-T5, single side of pack	1
3.1.11	Silicone heater pad 48 V × 200 W	Chinese supplier (◇ §12.3); bonded to heat-spreader via 3M VHB 4910	1
3.1.12	Thermal fuse KSD301 60 °C N.C.	Standard, 250 V / 10 A	1
3.1.13	External SSR 40 A DC	Crydom DRA1-CMP2450	1
3.1.14	CPCM composite panels — graphite foam + paraffin	SGL Carbon SIGRATHERM ePCM (T_phase +25 °C, ~190 J/g)	4 panels, ~2.06 kg total
3.1.15	Silica aerogel mat 20 mm, self-adhesive	UL 94 V-0; 3 sides + heater-side outer	stack perimeter
3.1.16	Foamglas T4+ block 40 mm with milled BMS window	Pittsburgh Corning / Foamglas T4+, A1 non-combustible, monolithic	1
3.1.17	PC 80M Mortar antiabrasive coating	Pittsburgh Corning, applied to all Foamglas exposed surfaces	~0.25 kg mixed/module
3.1.18	Filament tape / PET banding for outer retainer	Industrial fiberglass-reinforced filament tape (3M 8959 or equivalent)	~10 m/module
3.1.19	Inner heatshrink (cells + heat-spreader)	Polyolefin, UL 224 VW-1	1 section
3.1.20	M4 ring terminals Cu-Al bimetal	Tinned	17
3.1.21	Anti-oxidation compound	Noalox / Penetrox-A	1 tube/batch
3.1.22	Kapton (polyimide) tape 25 mm	NTC + harness collars	as needed
3.1.23	Techflex nylon braid ⌀ 5 mm	Balance harness sleeving	harness length

3.2 Power topology BOM

Item	Component	Vendor / model	Qty
3.2.1	Class-T fuse 300 A, 160 V DC, 20 kA	Mersen A3T-300 (or Bussmann FWX-300)	1
3.2.2	Class-T fuse holder	Mersen 60308R or eq	1
3.2.3	DC contactor 200 A, 1500 V DC	Gigavac GX14CAB, 12 V coil	1
3.2.4	Precharge relay 12 V / 30 A	Panasonic AHES4291	1
3.2.5	Precharge resistor 47 Ω / 50 W	Vishay RH050 aluminum-housed	1
3.2.6	Lockable rotary service disconnect 100 A	Schneider VBF or Eaton P3-100	1
3.2.7	Dielectric thermal pad 3–5 kV	Bergquist Sil-Pad 1500ST or Laird Tflex 6100	1 sheet
3.2.8	Power cable 25 mm² (×4) B− and P− dual-channel	Custom assembly	4 × ~150 mm
3.2.9	Power cable 50 mm² pack +	Cell 16 → fuse → disconnect → contactor → SurLok+	1 × ~400 mm
3.2.10	PE cable 6 mm² yellow-green	2 × earth points	2 × ~250 mm

3.3 Enclosure BOM

Item	Component	Vendor / model	Qty
3.3.1	Extruded Al 6063-T5 profile	Custom: 300 × 250 mm external, 2.5 mm base wall, with internal rails 5 × 10 mm (4 pcs), M8 bosses (8 pcs), screw bosses for cover screws (4 pcs), T-slots and stiffening ribs. Tooling ~$20k.	1 cut to 1280 mm
3.3.2	Stainless steel threaded inserts M8	Helicoil Tangless or Keensert KN0-080, AISI 304	8 (in M8 bosses)
3.3.3	White reflective powder coating	RAL 9003 or 9010, TiO_2 pigment, exterior	Surface coverage
3.3.4	Bottom cover assembly (Al 3 mm + FIPG)	Glued-in factory; sealed permanently with polyurethane FIPG (Sika Sikaflex-552 or Loctite SI 5980)	1
3.3.5	Top cover (Al 3 mm removable)	Flat plate, peripheral groove for silicone cord gasket	1
3.3.6	Silicone cord gasket ⌀ 5 mm	Trelleborg, Freudenberg or equivalent; −60…+200 °C, UV-stable, fitted in top cover groove	1 × ~1.2 m
3.3.7	Cover fastening screws	DIN 7991 M5 × 16, countersunk, AISI A2 stainless	14 per cover (top)
3.3.8	Donaldson Dual-Stage Jet pressure vent	Donaldson; 97 L/h breathing @ 10 mbar normal; cap release 100 L/s @ 100 mbar emergency	1 (in top cover)
3.3.9	M16 drain port labyrinth cap	Standard IP67 drain plug	1 (in bottom cover, factory-installed)
3.3.10	Silica gel desiccant cartridge	1000 g, indicator-type, replaceable	1
3.3.11	SurLok Plus 8 mm panel-mount red/black IP67	Amphenol SLPPA-8AAFP	2
3.3.12	M12 D-coded panel-mount female IP67	Phoenix or Binder	1
3.3.13	M12 A-coded panel-mount female IP67	Phoenix or Binder	1
3.3.14	LED status window (polycarbonate)	UV-stable, transparent	1
3.3.15	Eye-bolts M10 for lifting	DIN 580, stainless	2 (in top cover)

CE basis: EU 2011/65/EU + 2015/863 RoHS · REACH 1907/2006
TÜV / IEC basis: IEC 62619:2022 §5.1 — Critical component documentation
Verification: Material Declaration and REACH compliance from each supplier in technical file.

4. Pack architecture

4.1 Cell — XDLE CBA71173204-314Ah

Manufacturer	XDLE (Xingdong Lithium Battery), Hebei, China · Contact: Lulu Zhang
Model	CBA71173204-314Ah
Chemistry	LFP / LiFePO4, Z-stacking
Dimensions T × W × L	71.4 × 173.8 × 204.96 mm
Weight	5.6 ± 0.12 kg
Nominal voltage	3.2 V
Voltage range	2.5 V – 3.65 V
Nominal capacity	314 Ah at 0.5C, 25 °C
Initial clamping pressure	300 ± 30 kgf (datasheet §9 remark b)
Required cell-level certifications	IEC 62619, UN 38.3, RoHS, CE — ◇ §12.2

⚠ **WARNING:** XDLE-specific IEC 62619 / UN 38.3 / RoHS / CE certificates for CBA71173204-314Ah are pending. Without them, TÜV certification of the GT module cannot proceed. See §12.2.

4.2 Cell compression — aluminum cage

Cage	Al 6082-T6 anodized: endplates 10 mm + side rails
Tie-rods	4 × M8 grade 8.8 stainless A2, DIN 976
Preload springs	Belleville washers M8 DIN 2093 A8 (2 series × 2 parallel per rod)
Buffer pads	Silicone foam 1.5–2 mm, 15 pads
Initial preload	300 ± 30 kgf, verified by load cell
M8 rod torque	~ 12 N·m
Re-tension check	After first 50 thermal cycles; within ±10 %

CE basis: EU 2006/66/EC §3
TÜV / IEC basis: IEC 62619:2022 §7.2.4 · XDLE datasheet §9 (b)
Verification: Load cell calibrated annually; preload logged per module.

4.3 BMS — JK-PB2A16S20P

Model	JK-PB2A16S20P, doc V15.4.1
Cell count	16S LFP
Continuous current	200 A discharge
Active balance	2 A energy-transfer
Voltage accuracy	±3 mV per cell
Temperature inputs	1 internal + 4 external NTC (10 kΩ, B = 3950)
Communication	Bluetooth, RS485 ×2, CAN 250k, RS232
Heating control	Logic-level HEAT signal to external SSR
Dimensions	300 × 100 × 35 mm (with shield)
BMS-to-enclosure dielectric	Bergquist Sil-Pad / Laird Tflex, 3–5 kV breakdown — mandatory

4.4 NTC placement

4 external NTC sensors bonded to busbars between cells:

NTC	Location
NT1	Busbar between cells 2–3 (group 1–4)
NT2	Busbar between cells 6–7 (group 5–8)
NT3	Busbar between cells 10–11 (group 9–12)
NT4	Busbar between cells 14–15 (group 13–16)

4.5 Balance harness

17 conductors (B0–B16 + 4 NTC) routed through Techflex nylon braid ⌀ 5 mm with Kapton reinforcement collar at heatshrink exit. Distributed to 4 HY2.0 connectors (P5–P8) on BMS. Ring terminals M4 Cu-Al bimetal. Anti-oxidation compound on all Cu-Al joints. M4 torque 1.2 N·m.

CE basis: EU 2014/35/EU — wiring integrity
TÜV / IEC basis: IEC 62619:2022 §7.2.7 · IPC/WHMA-A-620 Class 2
Verification: 100% visual inspection; voltage step verification before BMS connection.

5. Power topology

5.1 Architecture

Two independent disconnects on pack-positive: Class-T fuse (passive, overcurrent), DC contactor (active, commanded by CE board). Plus rotary disconnect (manual, lockable) for service. BMS dual-channel MOSFETs on pack-negative. Satisfies IEC 62619 §8.3 with margin.

Pack +: Cell 16 (+) —▶ 50 mm² —▶ Class-T fuse 300 A —▶ Rotary disconnect (lockable) —▶ DC contactor GX14 —▶ SurLok+

└—▶ 2.5 mm² —▶ BAT+ M3 └—▶ precharge: 47 Ω + AHES4291 (2 s)

Pack −: Cell 1 (−) —▶ B− M6 ×2 (dual-channel) —▶ [BMS MOSFETs] —▶ P− M6 ×2 —▶ SurLok−

Heater: BMS HEAT M3 (logic) —▶ SSR control input

SSR power: +48 V —▶ SSR output —▶ KSD301 —▶ single heater on Al heat-spreader —▶ cell 1 (−)

⚠ **WARNING:** Pack positive does NOT pass through BMS. BAT+ M3 carries only BMS supply (~50 mA).

5.2 Service disconnect sequencing

✓ **Decision:** Lockable rotary disconnect placed AFTER Class-T fuse and BEFORE DC contactor. Order from cell: cell → fuse → manual disconnect → contactor → SurLok+. Rotary contacts are protected from arc-fault energy by upstream Class-T fuse.

CE basis: EU 2014/35/EU — overcurrent upstream of switching

TÜV / IEC basis: IEC 62619:2022 §8.3 · NEC 480.5 / ABYC E-11

Verification: Single-line diagram; fault simulation shows fuse trips before rotary contacts can weld.

5.3 Dual-channel B− / P−

Both M6 screws on B− and both on P− wired. Two independent 100 A legs internally. Two 25 mm² cables per side, identical brand and length.

5.4 BMS configuration

Parameter	Value
Cell type	LiFePO4 (16S)
Capacity	314 Ah
Overcharge / recovery	3.60 V / 3.54 V per cell
Undervoltage / recovery	2.60 V / 2.65 V per cell
Balance trigger Δ	10 mV; start ≥ 3.00 V/cell
Discharge overcurrent	200 A

Parameter	Value
Short circuit (BMS pre-stage)	300 A / 20 µs
Charge low-temp ON / OFF	+3 °C / +7 °C → drives external SSR
RS485-2 baud	115200

6. Thermal management (single-side architecture)

6.1 Concept

Asymmetric three-stage thermal strategy with single-side active components:

1. Active heating — single 200 W silicone heater bonded to Al heat-spreader plate (2 mm), placed against ONE side of cell stack (opposite to BMS)
2. Passive buffering — CPCM (composite phase change material): 4 rigid graphite-foam panels infused with paraffin, on outer side of heater
3. Asymmetric insulation — silica aerogel on 3 sides + Foamglas with antiabrasive coating on BMS side

6.2 Heater configuration

✓ **Decision:** Single silicone heater 48 V × 200 W bonded to anodized aluminum heat-spreader plate (2 mm). Placed flat against ONE side of cell stack (the side opposite to BMS). Heat conducts through cells via copper busbars (high λ) which act as internal heat distributors. No second heater needed.

Layer order on heater side (from cell outward):

- Cell stack
- Al heat-spreader 2 mm (anodized, in direct contact with cell faces)
- Silicone heater pad 0.75 mm bonded to heat-spreader via 3M VHB 4910
- CPCM panels (4 × SIGRATHERM ePCM, ~12 mm total)
- Inner heatshrink (UL 224 VW-1)
- Aerogel 20 mm
- Filament tape outer retainer

CE basis: EU 2006/66/EC §3

TÜV / IEC basis: IEC 62619:2022 §7.3.1 (charge thresholds + heating) · IEC 62619:2022 §8.3 (SSR + KSD301 = two protective layers)

Verification: Climate-chamber heating activation test −20 °C → +25 °C; SSR fault-injection (stuck-ON) verifies KSD301 trips at 60 °C.

6.3 CPCM thermal buffer

✓ **Decision:** Replace liquid paraffin in laminated pouches with rigid composite PCM panels: graphite foam matrix infused with paraffin (SGL Carbon SIGRATHERM ePCM, T_phase = 25 °C). Four panels per pack, total ~2550 cm³ / ~2.06 kg.

Material	Composite PCM: open-cell graphite foam impregnated with paraffin wax
Brand	SGL Carbon SIGRATHERM ePCM (or equivalent L/PCM)
Phase change temperature	25 ± 1 °C
Latent heat	~190 J/g (paraffin content)
Thermal conductivity	25–30 W/(m·K) — orders of magnitude higher than pure paraffin (0.2 W/m·K)
Mass per module	~2.06 kg (4 panels, ~12 mm thick each)
Total latent buffering capacity	~390 kJ

Leak risk	None — paraffin retained in graphite micropores by capillary action; rigid panels with no fluid risk
Cycle life	10 000+ phase cycles, no degradation (graphite matrix prevents segregation)
Form	Flat rigid panels, cut to size by vendor
Fire rating	Non-flammable matrix (graphite); UL 94 V-0 for the paraffin in micropores

ℹ **Note:** CPCM advantage over liquid PCM: (a) high thermal conductivity distributes heat uniformly across the pack — no hot spots, (b) rigid panels eliminate leak risk above +100 °C even if outer containment fails, (c) easier assembly — slide panels into place vs. fitting flexible mat. Mylar secondary containment from previous spec versions is no longer required.

6.4 Asymmetric insulation

Side	Material	Thickness	Function
Heater side (one long side)	Aerogel mat (over CPCM + heater + heat-spreader)	20 mm	Outer thermal barrier
Top and bottom (short sides)	Silica aerogel mat	20 mm	λ = 0.019 W/(m·K), self-adhesive, UL 94 V-0
BMS side (one long side)	Foamglas T4+ cellular glass with milled BMS window	40 mm	λ = 0.040 W/(m·K), A1 non-combustible. Window receives BMS
Foamglas surface treatment	PC 80M Mortar antiabrasive coating	~0.6 mm on all exposed surfaces	Pittsburgh Corning two-component slurry; prevents glass-dust generation under vibration

✓ **Decision:** Foamglas window is machined from one monolithic block (not assembled from cut pieces). PC 80M Mortar coating applied to all surfaces of Foamglas — including the surface facing the BMS, the surface facing the cell stack, and the surfaces facing the enclosure wall. Cure time 3 hours at +25 °C; verified by dust-test after cure.

CE basis: UL 94 V-0 / EN 60695 flammability · EN 13501-1 A1 non-combustible classification for Foamglas

TÜV / IEC basis: IEC 62619:2022 §7.3.7 (Thermal propagation containment)

Verification: Vibration test (UN 38.3 T.3) on first article confirms zero abrasive dust at PCB surface after test.

6.5 Outer retainer — filament tape banding

✓ **Decision:** The complete thermal sandwich (heater + heat-spreader + CPCM + aerogel + Foamglas) is held against the cell stack by industrial fiberglass-reinforced filament tape (3M 8959 or equivalent). 4–5 turns wound circumferentially with cross-pattern at top and bottom. Replaces epoxy retaining sleeve from previous spec versions — eliminates cure time and simplifies disassembly for repair.

CE basis: EU 2014/35/EU — mechanical integrity

TÜV / IEC basis: IEC 62619:2022 §7.2.4

Verification: Pull-test on tape junction per IPC/WHMA-A-620. Re-test after thermal cycling 1000 cycles.

7. Enclosure

7.1 Extruded aluminum profile

Material	Al 6063-T5 anodized (λ = 201 W/(m·K), yield 172–214 MPa)
External dimensions	300 × 250 mm (W × D), cut to length 1280 mm
Base wall thickness	2.5 mm
Internal cavity	295 × 245 mm (between walls)
Internal pack guide rails (longitudinal)	4 × 5 mm height × 10 mm width, on the two long (W=300) walls, full length of profile. Pack slides between rails during assembly. Pack-to-rail clearance: ~3.5 mm each side
Corner stiffening ribs	4 corners, 8 × 8 × 3 mm triangular fillets
M8 bosses (lateral stack)	8 × on long walls, locally thickened. Helicoil Tangless or Keensert KN0-080 (AISI 304) pressed at production
Cover-screw bosses	4 × longitudinal screw channels for self-tapping M5, located in 4 internal corners. Cross-section: ⌀ 4.2 mm channel with open longitudinal slot. Full length of profile
External finish	White reflective powder coating (RAL 9003 or 9010, TiO_2 pigment)
Tooling	Single extrusion mold, one-time ~$20k
Per-unit material cost	~$4/kg × ~18 kg ≈ $72

⚠ **WARNING:** Helicoil / Keensert inserts in M8 bosses are mandatory. Bare aluminum threads will gall and strip over a 10-year outdoor service life with thermal cycling.

7.2 Bottom cover — FIPG sealed (factory permanent)

✓ **Decision:** Bottom cover is sealed permanently at the factory using Form-In-Place Gasket (FIPG) polyurethane sealant (Sika Sikaflex-552 AT or Loctite SI 5980). Bottom cover is NOT user-serviceable. Service access only through removable top cover.

Bottom plate	Al sheet 3 mm, machined for M16 drain port
FIPG sealant	Sika Sikaflex-552 AT (polyurethane, UV-stable, −40…+90 °C service)
Application	Robot-dispensed continuous bead at factory; plate bolted with internal hex screws; sealant cures in 24 h
Curing	Skin time 60 min, full cure 24 h at +23 °C / 50% RH
Drain port	M16 IP67 labyrinth cap (passes condensate but not pressurized water)

CE basis: EU 2014/30/EU — sealed bottom prevents moisture ingress to electronics

TÜV / IEC basis: IEC 60529 (IP65) · IEC 62619:2022 §7.2.4 (mechanical integrity)

Verification: IP65 leak test per IEC 60529 14.2.5: water spray 12.5 L/min, 3 min, no ingress.

7.3 Top cover — removable, silicone-gasketed

✓ **Decision:** Top cover is a removable Al plate (3 mm) fastened to the extruded profile via 14 countersunk DIN 7991 M5 × 16 screws (A2 stainless) into longitudinal screw bosses in the four internal corners of the profile. Silicone cord gasket ⌀ 5 mm in a peripheral groove provides sealing.

Cover plate	Al 3 mm, machined: peripheral groove for gasket, holes for screws (countersunk), aperture for Donaldson vent, lifting eye-bolt mounts (×2)
Gasket	Silicone cord ⌀ 5 mm (Trelleborg, Freudenberg or eq), −60…+200 °C, UV-stable. Fitted in 4 × 4 mm peripheral groove. Compresses to ~4 mm when cover torqued
Screws	DIN 7991 M5 × 16, countersunk, AISI A2 stainless. 14 per cover (4 on each long side, 3 on each short side)
Screw torque	3.5 N·m, applied in 2 passes (50% → 100%, cross-pattern)
Screw bosses	Longitudinal in 4 internal corners of profile; self-tapping channel ⌀ 4.2 mm. Screws cut their own thread on first installation
Lifting points	2 × M10 eye-bolts (DIN 580) at opposite corners of cover
Donaldson vent aperture	Central or off-center, machined to vent mounting flange
Cover removal	Service technician unscrews all 14 screws, lifts cover. Replaces cover and re-torques in 2 passes

ℹ **Note:** Silicone is preferred over EPDM for outdoor cabinet: higher UV-stability (~20 yr vs ~10 yr), wider temperature range (−60…+200 °C vs −40…+120 °C), lower compression set (15% vs 25% at 70 °C / 1000 h). Premium of €2–3 per module is justified by service life and outdoor exposure.

CE basis: EU 2014/30/EU EMC — RF gasket continuity for shielding (silicone with embedded conductive option if needed)

TÜV / IEC basis: IEC 60529 (IP65)

Verification: Cover sealing tested after 100 thermal cycles −20…+50 °C: no IP65 degradation.

7.4 Pressure relief and venting

✓ **Decision:** Donaldson Dual-Stage Jet vent in the top cover. Normal mode: breathing membrane equalizes pressure during ambient cycling (97 L/h at 10 mbar). Emergency mode: at ≥ 100 mbar internal overpressure (cell venting / thermal runaway) the protective cap releases and discharges gas at up to 100 L/s.

Additional measures:

- Silica gel desiccant cartridge inside enclosure (1000 g, indicator-type, replaceable at annual service)
- M16 labyrinth drain in bottom cover for condensate
- In stacked configurations, each enclosure has its own independent vent — no shared vent plenum

CE basis: EU 2006/66/EC §3 — safety in foreseeable abuse · EU 2014/30/EU EMC — shielded transition belt cable channels

TÜV / IEC basis: IEC 62619:2022 §7.3.7 (Thermal propagation containment) · UN 38.3 Rev.7 T.2 (Thermal cycling)

Verification: Internal pressure ramp test confirms cap release at 100 mbar ± 10%. Vibration test confirms cap retention in normal mode.

7.5 BMS heat-sinking and dielectric isolation

✓ **Decision:** BMS mounted in Foamglas window in direct thermal contact with inside of enclosure wall through dielectric thermal pad (Bergquist Sil-Pad 1500ST or Laird Tflex 6100, 3–5 kV breakdown). Aluminum wall acts as passive heat sink (~0.25 m² area for 20–30 W BMS dissipation).

CE basis: EU 2014/35/EU — touch-safety dielectric isolation

TÜV / IEC basis: IEC 62619:2022 §8.2.4 (External terminals)

Verification: Dielectric breakdown test; thermal imaging under simulated solar load (+50 °C ambient, full sun).

7.6 Stacking topology

Vertical stacking	Through a separate, wider extruded transition belt between top of lower enclosure and bottom of upper enclosure
Transition belt — cable routing	Two independent shielded channels: DC power and RS485 (EMC)
Transition belt — venting	NO shared vent. Each enclosure vents independently
Lateral stacking	Wall-to-wall via M8 bolts through stainless inserts in side bosses

7.7 FEM (Front End Module) interface

All interfaces on one short end face of enclosure. The FEM panel is integral with the enclosure profile (factory-machined apertures), not a removable panel. SurLok Plus +/−, M12 D-coded, M12 A-coded, lockable rotary disconnect, two M5 PE points on opposite edges, LED status window.

7.8 Internal airflow gap

✓ **Decision:** 10–15 mm air gap between outer surface of insulation (aerogel / Foamglas / filament tape) and inside surface of enclosure walls. Functions:

- Drainage path for condensate to bottom drain port
- Buffer volume for gas in emergency vent scenarios
- Assembly tolerance allowing pack to slide along internal rails without damaging insulation
- Convective cooling of BMS through aluminum wall heat-sinking

8. Assembly procedure

Step-by-step. Every step logged in Production Log.

8.1 Pack assembly

4. Incoming inspection of 16 cells (same XDLE lot; V spread ≤ 20 mV; IR spread ≤ 5%)
5. Stack cells with 15 buffer pads; insert into Al cage with endplates; tension M8 tie-rods alternately; verify preload 300 ± 30 kgf with load cell
6. Install busbars; torque cell terminals per XDLE datasheet
7. Install 17 balance leads with M4 ring terminals; anti-oxidation compound; 1.2 N·m torque
8. Install 4 NTC sensors on busbars (thermal paste + Kapton 3–4 layers)
9. VOLTAGE STEP VERIFICATION — measure each BMS pin to B0, monotonic 0…51.2 V; do NOT connect to BMS if any deviation
10. Apply inner heatshrink to cell stack (excluding heater side)

8.2 Thermal stack-up (heater side only)

11. Bond silicone heater 200 W to Al heat-spreader 2 mm via 3M VHB 4910; press 30 s
12. Place heat-spreader + heater against one long side of cell stack (opposite to BMS-designated side)
13. Place 4 × SIGRATHERM CPCM panels over heater (~12 mm total thickness)
14. Apply aerogel mat 20 mm over CPCM (self-adhesive)

8.3 Insulation — other sides

15. Apply aerogel mat 20 mm to top and bottom of pack (self-adhesive)
16. Pre-coat Foamglas block (already with milled BMS window) with PC 80M Mortar on all exposed surfaces; cure 3 h at +25 °C
17. Place Foamglas block on the BMS-designated side of pack (against cells)

8.4 Outer retainer

18. Wrap pack with filament tape (3M 8959 or eq): 4–5 circumferential turns + cross-pattern at top and bottom
19. Verify tape tension uniformity; no slack

8.5 BMS mounting

20. Install dielectric thermal pad (Bergquist Sil-Pad 1500ST) on BMS heat-sink surface
21. Insert BMS into Foamglas window; press against external orientation (BMS will face enclosure wall after pack insertion)
22. Wire BMS: B− M6 ×2 (25 mm² parallel), P− M6 ×2, BAT+ M3 (2.5 mm²), HEAT M3 logic to SSR
23. Plug 4 balance HY2.0 connectors (only after step verification)

8.6 Power topology assembly

24. Wire from cell 16 (+) through Class-T fuse → rotary disconnect → Gigavac GX14 contactor → SurLok+ panel-mount
25. Mount precharge relay AHES4291 + Vishay RH050 resistor in parallel with contactor
26. Wire SurLok− to BMS P−; both connector HVIL pins to M12 control connector

8.7 Enclosure assembly

27. Verify Helicoil inserts pressed in all M8 bosses (factory-installed)
28. Verify bottom cover FIPG-sealed (factory-installed, not field-replaceable)
29. Apply white powder coating if not factory-applied (RAL 9003 or 9010)
30. Slide pack into enclosure along internal rails 5 × 10 mm, from top opening, FEM-side first
31. Verify pack alignment: BMS dielectric pad in firm contact with one long wall; thermal layers do not bind on rails
32. Connect all panel-mount connectors on FEM end (SurLok +/−, M12 ×2, PE ×2)
33. Install Donaldson Dual-Stage Jet vent in top cover aperture
34. Install silica gel desiccant cartridge in dedicated holder

8.8 Top cover installation

35. Lay silicone cord gasket ⌀ 5 mm in peripheral groove of cover
36. Apply small dab of grease (silicone) on screw threads (first installation thread cutting)
37. Align cover with enclosure profile; lower in place
38. Insert 14 × DIN 7991 M5 × 16 screws (countersunk, A2 stainless) into screw bosses
39. First pass: 50% torque (1.75 N·m), cross-pattern
40. Second pass: 100% torque (3.5 N·m), cross-pattern
41. Verify cover seal: gasket compression uniform around perimeter, no visible gaps

8.9 First power-up

42. Verify Anderson voltage 51.2 ± 2 V at SurLok terminals
43. Activate BMS via charger or external on/off; Bluetooth JK app verification
44. Load BMS configuration per §5.4; set heating thresholds +3 °C / +7 °C
45. Heating test: simulate low-temp → SSR closes → heater current as expected
46. Contactor test: close from CE board → pull-in ≤ 20 ms
47. Precharge test: inrush peak ≤ 10 × nominal
48. HVIL test: simulate connector unplug → contactor opens ≤ 20 ms
49. Active balancing 8–24 h if cell V spread > 10 mV

9. Quality control and pre-shipment testing

9.1 Per-module tests

#	Test	Acceptance
1	Insulation: enclosure ↔ power terminals	> 100 MΩ @ 500 V DC
2	BMS dielectric pad breakdown	> 3 kV
3	PE continuity (both M5 points)	< 0.1 Ω
4	16 cell voltages post-balance	3.20–3.30 V, spread ≤ 10 mV
5	Pack IR @ 1 kHz	≤ 5 mΩ
6	Discharge 200 A × 10 min	ΔV ≤ 3 V, no trips
7	Charge 0.2C × 30 min @ +25 °C	Normal
8	Heater + SSR activation	Current as expected; SSR closes
9	Contactor close/open	≤ 20 ms / ≤ 10 ms
10	Precharge inrush	Peak ≤ 10 × nominal
11	HVIL response	Contactor opens ≤ 20 ms
12	RS485 Modbus	All BMS registers readable
13	Bluetooth JK app	Connects, all parameters
14	SurLok contact resistance	≤ 0.5 mΩ
15	Class-T fuse continuity	< 0.5 mΩ
16	Rotary disconnect	Smooth, lockable in OFF
17	Enclosure IP65 leak test	No water ingress 12.5 L/min spray 3 min
18	Cover screw torque audit	All 14 screws at 3.5 ± 0.3 N·m
19	Visual inspection	All layers; coatings intact; Foamglas dust test (vacuum + wipe = no glass particles)

CE basis: EU 2006/66/EC — production verification

TÜV / IEC basis: IEC 62619:2022 §8.2.2 · ISO 9001:2015 §8.6

Verification: QA signatures per module; records retained 10 years.

9.2 Per-batch sample tests

- UN 38.3 T.3 vibration + T.4 shock — 1 module per batch
- IEC 62619 §7.2.3 drop test (25 mm edge + corner) — 1 module per batch
- IEC 62619 external short-circuit (validates Class-T fuse) — 1 module per batch
- Full cycle at −20 / +25 / +45 °C — 1 module per batch
- Donaldson vent emergency release pressure test — 1 module per batch
- Cover seal pressure leak test after 100 thermal cycles — 1 module per quarter
- Contactor 1000 close/open cycles — 1 module per quarter

9.3 Production Log

- Serial GT-BAT-YYYYMMDD-NNNN, date, operator, XDLE cell lot, BMS lot, CPCM panel lot
- 16 cell voltages and IRs; compression preload; stack thickness
- BMS, contactor, fuse, SSR, vent, dielectric pad serials
- Cover screw torque audit (14 values)
- All 19 QC test results
- BMS firmware version + config file
- CFP data linked to module serial (per EU 2023/1542)
- QA inspector signature

10. Marking, packaging, batch documentation

10.1 Marking

- Serial GT-BAT-YYYYMMDD-NNNN (laser-engraved metal plate on FEM)
- QR code → digital module passport per EU 2023/1542
- Nominal: 51.2 V / 314 Ah / 16 kWh
- SurLok polarity (+/−)
- IP65, Class 9 transport
- CE, UN 38.3, IEC 62619 marks (post-certification)
- Li-ion / do not incinerate / do not open
- Crossed-out wheelie bin (Battery Directive)
- Date of manufacture, country, GT GmbH Berlin

10.2 Transport packaging

- Wooden crate, shock-absorbing inserts (IATA / ADR UN3480)
- Module SoC 30 ± 5 % per UN 38.3
- SurLok and M12 connectors capped
- BMS in transit mode
- MSDS per UN 38.3 §38.3.5

10.3 Batch documentation

- Batch certificate with serials
- Cell traceability — module ↔ XDLE lot
- BMS firmware log
- Material declaration — RoHS, REACH, Battery Regulation
- MSDS
- CFP declaration per module (EU 2023/1542)
- CE Declaration of Conformity (post-certification)

11. Standards compliance

11.1 CE Marking (self-declaration by GT)

EU directive / regulation	Scope	Conformity route
2014/35/EU LVD	Low Voltage Directive	Module 51.2 V DC below LVD scope; designed per harmonized principles
2014/30/EU EMC	EMC	EN IEC 61000-6-2 / -6-4 industrial; type test at accredited lab
2011/65/EU + 2015/863 RoHS	Restricted substances	Material declarations from each supplier
2006/66/EC + 2013/56/EU Battery Directive	Heavy metals, marking, collection	Cell-level compliance from XDLE; collection symbol applied
2023/1542 Battery Regulation	CFP, passport, due diligence, recycled content	See §11.4 — major obligations; CFP already mandatory
REACH 1907/2006	Chemicals	SVHC declarations in technical file

11.2 TÜV / Notified Body certification

Standard	Scope	Test
IEC 62619:2022	Industrial Li-ion battery safety	Certificate by notified body
IEC 62619:2022 §7.2.3	Drop test 25 mm (modules > 100 kg)	Edge + corner drop
IEC 62133-2:2017	Li-ion cell/battery safety	Combined with IEC 62619
UN 38.3 Rev.7	8 transport tests	Test summary §38.3.5
IEC 60068-2-6 / -27	Vibration / shock	Combined with UN 38.3 T.3/T.4
IEC 60529	IP code	IP65 enclosure
IEC 61000-6-2 / -6-4	EMC industrial	Type test
EN 13501-1	Reaction to fire	Foamglas A1 declaration

11.3 Functional safety — single-fault tolerance (IEC 62619 §8.3)

Hazard	Layer 1	Layer 2
Cell overvoltage	BMS blocks at 3.6 V	iONEOS / station supervisor
Cell undervoltage	BMS blocks at 2.6 V	Auto-shutdown at 2.5 V
Overcurrent (slow)	BMS trips 200 A / 3 s	Class-T fuse 300 A continuous

Hazard	Layer 1	Layer 2
Short circuit (fast)	BMS trips 300 A / 20 µs	Class-T fuse 20 kA interrupt
Cell over-temperature	BMS trips at +70 °C	iONEOS shutdown
Charge under-temperature	BMS blocks < 0 °C; activates heater	KSD301 thermal fuse
Heater stuck-ON failure	BMS removes HEAT → SSR opens	KSD301 60 °C N.C.
MOSFET short failure	Class-T fuse interrupts	DC contactor opens
Connector hot-unplug	HVIL breaks first	Contactor opens ≤ 20 ms
Cell thermal runaway gas	CPCM absorbs initial heat (graphite matrix dissipates)	Donaldson Dual-Stage Jet releases at 100 mbar
CPCM matrix damage	Rigid graphite foam — no leak path	Filament tape outer retainer holds panels in place
Foamglas dust under vibration	PC 80M Mortar coating on all surfaces	Monolithic block (no glue joints)
BMS-to-enclosure short	Dielectric pad 3–5 kV breakdown	Dual PE bonding
Moisture ingress (bottom)	FIPG permanent seal	M16 labyrinth drain
Moisture ingress (top)	Silicone cord gasket compressed by 14 screws	Donaldson breathing membrane
Cu-Al galvanic corrosion	Bimetal ring terminals	Anti-oxidation compound Noalox

11.4 EU Battery Regulation 2023/1542 — compliance plan

⚠ **CRITICAL DEADLINE:** Carbon Footprint Declaration is MANDATORY since February 2026 for industrial batteries > 2 kWh. GT must close §12.6 immediately before first commercial shipment. Without third-party verified CFP, the product cannot legally be placed on the EU market.

11.4.1 Carbon Footprint Declaration (mandatory since Feb 2026)

Methodology	PEFCR for Rechargeable Batteries (Product Environmental Footprint Category Rules)
Functional unit	1 kWh delivered energy over service life
System boundary	Cradle-to-grave: raw materials → cell manufacturing → module assembly → use phase → end-of-life recycling
Scope 1 (direct)	GT final assembly emissions (Berlin facility) — minimal, mostly cured FIPG sealant and adhesives
Scope 2 (energy)	Electricity used in assembly facility (Berlin grid factor)
Scope 3 (upstream)	XDLE cell production, JK BMS manufacturing, Al extrusion in China, transport — typically 80%+ of total

Third-party verification	Required by accredited body (TÜV Rheinland, SGS, DEKRA, or Bureau Veritas)
Output	Public CFP declaration per battery model; referenced in digital passport
Update frequency	Annual or on significant supply chain change

CE basis: EU 2023/1542 Art. 7 — Carbon footprint of batteries

TÜV / IEC basis: ISO 14067 Carbon footprint of products · PEF methodology

Verification: LCA study by accredited consultancy (Sphera, Quantis, or thinkstep) with full supplier data collection.

11.4.2 Digital Battery Passport (mandatory Feb 2027)

Format	Web-accessible record per individual module, addressable via QR code on the FEM marking plate
Hosting	GT internal database with public read API; redundant backup
Required contents (per Regulation Annex XIII)	
— Identification	Manufacturer (GT GmbH), model (iONE-BAT-314), serial, date of manufacture, place of manufacture
— Composition	Chemistry (LFP), cell material declaration, hazardous substances list
— Carbon footprint	Link to §11.4.1 CFP declaration with class (A through E)
— Supply chain due diligence	Summary report (§11.4.3)
— Manufacturing data	Factory, batch number, QA reference
— Performance data	Real-time SoH, cycle count, capacity fade (via iONEOS link); not static
— Recycled content	Per-material percentages of recycled Co, Li, Ni, Pb
— Disassembly instructions	Step-by-step procedure for safe disassembly and material separation
— Recycling information	Authorized recyclers in EU; collection point information
— Compliance certificates	IEC 62619, UN 38.3, CE Declaration of Conformity (PDFs linked)

CE basis: EU 2023/1542 Art. 77 + Annex XIII — Digital battery passport

TÜV / IEC basis: GS1 product identification standards (for QR code structure)

Verification: Database accessible by Member State market surveillance authorities; iONEOS feeds dynamic performance data automatically.

11.4.3 Supply chain due diligence (mandatory Aug 2027)

Per OECD Due Diligence Guidance for Responsible Supply Chains of Minerals. For LFP chemistry, critical materials are lithium and natural graphite. Cobalt and nickel are not in our chemistry but still relevant for BMS components and overall reporting.

Lithium carbonate supply chain	XDLE → Li carbonate supplier(s) → mine of origin. Audit chain quarterly
Natural graphite	Anode material in cells; trace to mine
Cobalt / nickel	Trace amounts in BMS components; declare ethically sourced
Required documentation	Supplier Code of Conduct signed by XDLE; mine-of-origin certificates; annual third-party audit reports
Audit body	TIC (Testing, Inspection, Certification) accredited firm (e.g., SGS, Bureau Veritas, TÜV)
Reporting	Annual due diligence report, published, referenced in digital passport

CE basis: EU 2023/1542 Art. 47–52 — Supply chain due diligence policy · OECD Due Diligence Guidance

TÜV / IEC basis: ISO 26000 social responsibility

Verification: Annual audit reports published; mine-of-origin traceability verified by independent auditor.

11.4.4 Recycled content targets (mandatory from 2031, planning required earlier)

Material	Target by 2031	Target by 2036
Lithium	6 %	12 %
Cobalt	16 %	26 %
Lead	85 %	85 %
Nickel	6 %	15 %

Although not immediately mandatory, GT must establish supplier reporting in 2026–2027 to meet 2031 targets. Recycled content data is required in the digital passport (§11.4.2).

11.5 Certification and compliance roadmap

Phase	Timeline	Action
Phase 1 — CFP urgent	Q2 2026 (NOW)	Engage LCA consultancy; collect data from XDLE, JK, Al supplier. CFP declaration MUST be ready before any EU sales
Phase 2 — Cell certs	Q3 2026	Close §12.2: XDLE IEC 62619 / UN 38.3 / RoHS
Phase 3 — Series-1 assembly	Q4 2026	Assemble 5 modules to series spec for TÜV submission and CFP validation
Phase 4 — TÜV scoping	Q4 2026	Engage TÜV Rheinland; scope IEC 62619 + IEC 62133-2 + UN 38.3 + CFP verification
Phase 5 — Testing + CFP verification	Q1 2027	Submit to TÜV lab; LCA verification by third party
Phase 6 — Certificates + CE	Q2 2027	Receive IEC 62619 + UN 38.3 summary + CFP verification; issue GT Declaration of Conformity; affix CE mark
Phase 7 — Series-1 launch	Q3 2027	Production 50 units under certified design with valid CFP
Phase 8 — Digital Passport	Q3 2027 (before Feb 2027 was missed deadline)	Passport database live; QR code on every module
Phase 9 — Due diligence	Aug 2027	Audit reports for XDLE supply chain
Phase 10 — Recycled content	Establish 2027; report from 2031	Supplier data collection for future 6%/16% targets

12. Open items

Closing these items is required for TÜV certification and EU 2023/1542 compliance.

12.1 Inter-cell buffer pads — material spec

◇ **Open:** PORON EVExtend or Saint-Gobain Norseal datasheet: density, CFD per ASTM D1056, compression set, UL 94 V-0.

12.2 XDLE cell certifications

◇ **Open:** IEC 62619 + UN 38.3 + RoHS + CE certificates for CBA71173204-314Ah issued specifically by XDLE. Existing HUAK reports apply to Hebei Juyuan cells (different manufacturer).

12.3 Heater supplier

◇ **Open:** Chinese supplier of silicone heating pad 48 V × 200 W with Al heat-spreader bonding compatibility, UL 94 V-0, −40…+150 °C.

12.4 Busbars specification

◇ **Open:** From XDLE: material (Al / Cu / Cu-Al), cross-section, 200 A continuous rating, M4/M5 stud size, torque, welded stud confirmation.

12.5 Extrusion mold final design

◇ **Open:** Final 2D cross-section drawing: 300 × 250 external, 2.5 mm wall, 4 × internal rails 5 × 10 mm, 4 × corner screw bosses for self-tapping M5, 8 × M8 lateral bosses with Helicoil pockets, T-slots, anodizing spec. Tooling ~$20k; lead 8–12 weeks.

12.6 EU 2023/1542 compliance — CRITICAL OVERDUE

⚠ **CRITICAL DEADLINE:** CFP declaration was mandatory from February 2026 — currently 3+ months overdue. Engage LCA consultancy IMMEDIATELY. Without CFP, no EU sales possible. See §11.4.1.

◇ **Open:** LCA study, supplier CFP data, third-party verification body, digital passport database, supply chain audit plan.

12.7 Serial tracking system

◇ **Open:** GT internal database with public read API for passport. Serial format. QR code content structure (GS1 standards).

12.8 SIGRATHERM ePCM panel sizing

◇ **Open:** Confirm exact dimensions and panel count with SGL Carbon. Target: 4 panels totaling ~2.06 kg, fitting 217 × 1180 × 12 mm footprint.

12.9 Bottom cover FIPG sealant qualification

◇ **Open:** Validate Sika Sikaflex-552 AT for 10–15 year outdoor service: UV, thermal cycling −20…+50 °C, polyurethane to Al 6063 anodized adhesion.

12.10 Module CFP supplier data — XDLE / JK / Al extrusion

◇ **Open:** Specific CFP data per kWh from each major supplier required for our LCA calculation. May require GT-led supplier engagement.

Appendix A. Glossary

Term	Definition
BAT+	BMS terminal (M3) for BMS supply only. Not a power-current path.
BMS	Battery Management System (JK-PB2A16S20P)
CFP	Carbon Footprint of Product (EU 2023/1542 Article 7)
Class-T fuse	DC-rated fuse class per UL 248-15
Contactor	High-current DC switch (Gigavac GX14)
CPCM	Composite Phase Change Material — graphite foam infused with paraffin (SIGRATHERM)
Dual-channel	BMS with two independent 100 A power legs
EU 2023/1542	EU Battery Regulation — replaces Directive 2006/66/EC
FEM	Front End Module — single end face of enclosure with all interfaces
FIPG	Form-In-Place Gasket — robot-dispensed polyurethane sealant cured in place
Foamglas	Cellular glass insulation, A1 non-combustible (Pittsburgh Corning)
Helicoil / Keensert	Stainless threaded inserts pressed into aluminum bosses
HEAT (logic)	BMS heater control output (M3, logic signal to external SSR)
HVIL	High-Voltage Interlock Loop — short pin breaks before power contacts
LFP / LiFePO4	Lithium Iron Phosphate cell chemistry
NTC	Negative Temperature Coefficient thermistor
P−	Pack Negative — BMS output (2 × M6 dual-channel)
PC 80M Mortar	Pittsburgh Corning two-component slurry; antiabrasive coating for Foamglas
PE	Protective Earth (yellow-green 6 mm² cable)
PEFCR	Product Environmental Footprint Category Rules — EU LCA methodology
Production Log	Per-module manufacturing record (IEC 62619 retention 10 years)
SIGRATHERM ePCM	SGL Carbon brand name for graphite-foam composite PCM
SoC / SoH	State of Charge / State of Health
SSR	Solid State Relay — switches heater current
SurLok Plus	Amphenol industrial EV-grade power connector with HVIL
Transition belt	Wider extruded profile between vertically stacked enclosures
XDLE	Xingdong Lithium Battery (cell manufacturer)

Appendix B. Standards reference

Standard	Title	Application
IEC 62619:2022	Industrial Li-ion battery safety	Primary certification target
IEC 62619:2022 §7.2.3	Drop test for modules > 100 kg	25 mm edge/corner drop (NOT UN 38.3 1.2 m)
IEC 62619:2022 §7.3.7	Thermal propagation containment	Foamglas + Donaldson + CPCM
IEC 62619:2022 §8.3	Single-fault tolerance	Class-T + contactor + BMS + KSD301
IEC 62133-2:2017	Li-ion cell/battery safety	Backup standard
UN 38.3 Rev.7	Transport testing of lithium batteries	8 tests (T.5 = external short, NOT drop)
IEC 60068-2-6 / -27	Vibration / shock	Combined with UN 38.3 T.3/T.4
IEC 60529	IP code	IP65
IEC 61000-6-2 / -6-4	EMC industrial	Type test
IEC 60947-4-1	Contactors	Gigavac GX14
UL 248-15	Class T fuses	Mersen A3T-300
EN 13501-1	Reaction to fire	Foamglas A1 classification
EU 2014/35/EU LVD	Low Voltage Directive	Below scope; documented
EU 2014/30/EU EMC	EMC Directive	CE marking
EU 2011/65/EU + 2015/863	RoHS 2/3	Hazardous substances
EU 2006/66/EC + 2013/56/EU	Battery Directive	Heavy metals (legacy; superseded by 2023/1542)
EU 2023/1542	EU Battery Regulation	CFP (Feb 2026), Passport (Feb 2027), Due Diligence (Aug 2027)
ECE R100 / UN R100	EV high-voltage safety	HVIL harmonization
REACH 1907/2006	Chemicals	SVHC
IPC/WHMA-A-620 Class 2	Cable / wire harness	Harness QA
ISO 9001:2015	QMS	GT QMS
ISO 14067	Carbon footprint of products	CFP methodology
PEFCR Rechargeable Batteries	Product Environmental Footprint Category Rules	Required CFP methodology
OECD Due Diligence Guidance	Responsible mineral supply chains	Supply chain audits
UL 94	Plastic flammability	V-0 rating
DIN 7991	Countersunk M5 screws	Cover fastening
DIN 580	Lifting eye-bolts	Top cover lifting points

Appendix C. Revision history

Version	Date	Notes
1.0	2026-05-16	First complete version. Withdrawn.
1.1	2026-05-17	Series-only with industrial upgrades. Withdrawn.
1.2	2026-05-17	Final-for-Audit. First integrated pack + enclosure + thermal. Withdrawn after second-round reviewer feedback.
1.3	2026-05-17	Current version. Major revisions: (1) PCM changed from liquid paraffin in pouches to CPCM rigid graphite-foam panels (SIGRATHERM ePCM), single-side configuration with one heater on Al heat-spreader; (2) Mylar secondary containment removed (CPCM has no leak path); (3) Epoxy retaining sleeve replaced by filament tape; (4) Bottom cover sealed permanently by FIPG polyurethane; (5) Top cover removable with silicone cord gasket + 14 DIN 7991 M5 screws into 4 longitudinal screw bosses in extrusion; (6) Internal pack guide rails 5 × 10 mm specified on long walls; (7) Complete EU 2023/1542 compliance plan added: CFP (mandatory since Feb 2026 — overdue), Digital Passport (Feb 2027), Supply chain due diligence (Aug 2027). All previous reviewer modifications retained: Helicoil inserts, white powder coating, PC 80M Mortar on Foamglas, Donaldson Dual-Stage Jet, dielectric pad, rotary disconnect after fuse, dual PE bonding.