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BSI Standards Publication

Railway applications — Batteries for auxiliary power supply systems

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National foreword

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The UK participation in its preparation was entrusted by Technical Committee GEL/9, Railway Electrotechnical Applications to Subcommittee GEL/9/2, Railway Electrotechnical Applications – Rolling stock.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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English version

Railway applications - Batteries for auxiliary power supply systems

Applications ferroviaires - Batteries pour systèmes d'alimentation auxiliaire

Bahnanwendungen - Batterien für Bordnetzversorgungssysteme

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

This document (EN 50547:2013) has been prepared by Working Group 20 of SC 9XB, Electromechanical material on board of rolling stock, of Technical Committee CENELEC TC 9X, Electrical and electronic applications for railways.

The following dates are fixed:

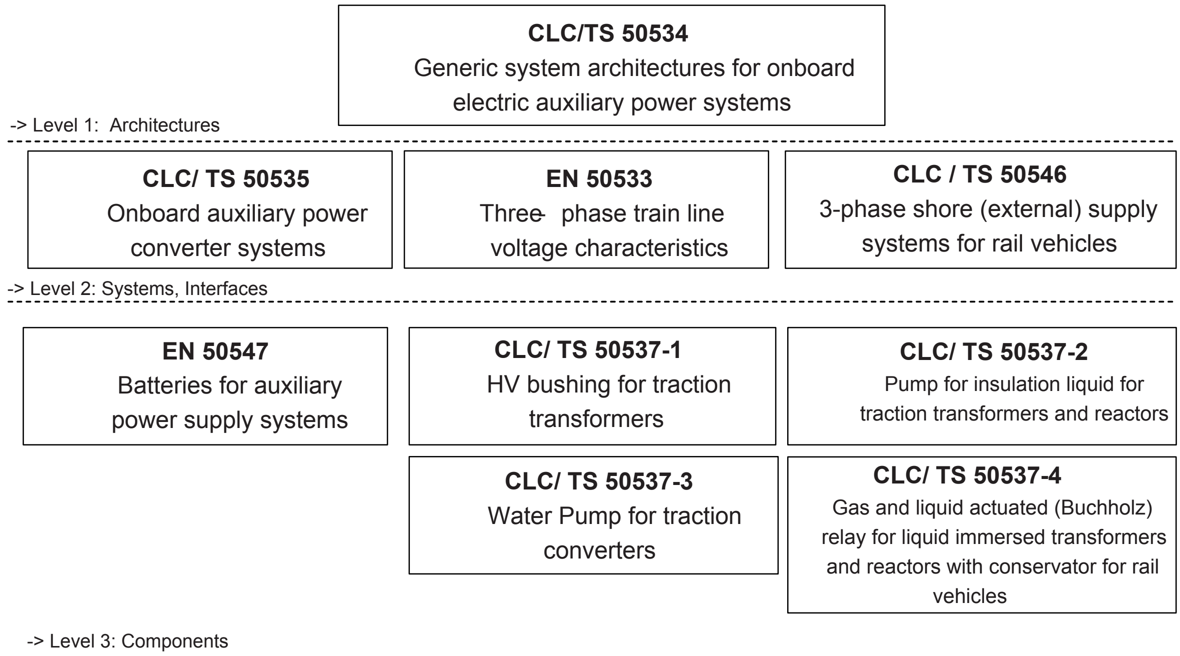
- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2014-03-04
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2016-03-04

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

EN 50547 shall be read in conjunction with CLC/TS 50534:2010 "*Railway applications - Generic system architectures for onboard electric auxiliary power systems*".

This standardization project was derived from the EU-funded Research project MODTRAIN (MODPOWER). It is part of a series of standards, referring to each other. The hierarchy of the standards is intended to be as follows:

Overview on the technical framework
CLC/TS 50534 defines the basis for other depending standards



1 Scope

This European Standard specifies rechargeable lead acid and NiCd-batteries for 110 V voltage auxiliary power supply system for railway vehicles.

This European Standard may be applied to other rolling stock types (e.g. light rail vehicles, tramways, metros…) if these are not in the scope of another specific standard.

Others technologies like NiMh or Lithium are not covered by this standard at present.

This European Standard focuses on:

- the description of mechanical interfaces: dimensions of the cells or monobloc batteries, main terminals and preferred sizes of the mounting space of the battery systems for lead acid batteries,
- the description of mechanical interfaces: dimensions of the trays and main terminals for NiCd batteries
(as they have different characteristics depending on the technology),
- description of electrical interfaces: capacity, voltage and charging characteristic.

This European Standard restricts the variety of different types provided by EN 60254 and EN 60896 for lead acid batteries and defines the use of cells compliant to EN 60623 and EN 62259 for NiCd-Batteries.

The main objective of this standard is to achieve interchangeability of the battery cells and monobloc for lead acid batteries and the interchangeability of the battery trays for NiCd batteries.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 50125-1:1999 *Railway applications - Environmental conditions for equipment - Part 1: Equipment on board rolling stock*

EN 50155:2007 *Railway applications - Electronic equipment used on rolling stock*

EN 50272-2:2001 *Safety requirements for secondary batteries and battery installations Part 2: Stationary batteries*

EN 50272-3:2002 *Safety requirements for secondary batteries and battery installations Part 3: Traction batteries*

EN 50467:2011 *Railway applications - Rolling stock - Electrical connectors, requirements and test methods*

EN 60077-1:2002 *Railway applications - Electric equipment for rolling stock - Part 1: General service conditions and general rules (IEC 60077-1:1999, mod.)*

EN 60254-1:2005 *Lead-acid traction batteries - Part 1: General requirements and methods of test (IEC 60254-1:2005)*

EN 60254-2:2008 *Lead-acid traction batteries - Part 2: Dimensions of cells and terminals and marking of polarity on cells (IEC 60254-1:2005)*

EN 60623:2001 *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Vented nickel-cadmium prismatic rechargeable single cells (IEC 60623:2001)*

EN 60896-11:2003	*Stationary lead-acid batteries - Part 11: Vented types; General requirements and methods of test (IEC 60896-11:2002)*
EN 60896-21:2004	*Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test (IEC 60896-21:2004)*
EN 61373:2010	*Railway applications - Rolling stock equipment - Shock and vibration test (IEC 61373:2010)*
EN 62259:2004	*Secondary cells and batteries containing alkaline or other non-acid electrolytes - Nickel cadmium prismatic secondary single cells with partial gas recombination (IEC 62259:2003)*
CEN/CLC TS 45545 series	*Railway applications - Fire protection on railway vehicles*
EN ISO 7010:2012	*Graphical symbols - Safety colours and safety signs - Safety signs used in workplaces and public areas (ISO 7010:2011)*
IEC 60410:1973	*Sampling plans and procedures for inspection by attributes*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

NOTE All typical battery related descriptions are defined in IEC 60050-482.

3.1.1
battery crate
container with frame walls for holding several cells or batteries

[SOURCE: IEC 60050-482:2004, 482-05-10]

Note 1 to entry: See Clause 7.

3.1.2
battery tray
container with a base and walls for holding several cells or batteries

[SOURCE: IEC 60050-482:2004, 482-02-35]

Note 1 to entry: See Clause 7.

3.1.3
cell
basic functional unit, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy

[SOURCE: IEC 60050-482:2004, 482-01-01]

3.1.4
lead acid battery
secondary battery with an aqueous electrolyte based on dilute sulphuric acid, a positive electrode of lead dioxide and a negative electrode of lead

[SOURCE: IEC 60050-482:2004, 482-05-01]

3.1.5
monobloc battery
battery with multiple separate but electrically connected cell compartments each of which is designed to house an assembly of electrodes, electrolyte, terminals or interconnections and possible separators

[SOURCE: IEC 60050-482:2004, 482-02-17]

Note 1 to entry: The cells in a monobloc battery can be connected in series or in parallel.

Note 2 to entry: See Clause 7.

3.1.6
nickel cadmium battery
secondary battery with an alkaline electrolyte, a positive electrode containing nickel oxide and a negative electrode of cadmium

[SOURCE: IEC 60050-482:2004, 482-05-02]

3.1.7
rated capacity of the battery
C_{rt}: capacity value of a battery determined under specified conditions and declared by the manufacturer

[SOURCE: IEC 60050-482:2004, 482-03-15]

3.1.8
valve regulated lead acid battery
secondary battery in which cells are closed but have a valve which allows the escape of gas if the internal pressure exceeds a predetermined value

[SOURCE: IEC 60050-482:2004, 482-05-15]

Note 1 to entry: The cell or battery cannot normally receive additions to the electrolyte.

3.1.9
vented cell
secondary cell having a cover provided with an opening through which products of electrolysis and evaporation are allowed to escape freely from the cell to the atmosphere

[SOURCE: IEC 60050-482:2004, 482-05-14]

3.2 Abbreviations

For the purpose of this document, the following abbreviations apply:

AC	Alternating Current
AGM	Absorbent Glass Mat
C_5	Capacity at the 5-hour rate
CCTV	Closed-Circuit Televison
DC	Direct Current
DoD	Depth of Discharge
EMU	Electrical Multiple Unit
FEM	Finite Elements Method
GEL	Gel filled battery
H	Height
HVAC	Heating, Ventilation, Air Conditioning
HST	High Speed Train
L	Length
LRU	Line replaceable Unit
LVPS	Low Voltage Power Supply
NiCd	Nickel Cadmium
NiMH	Nickel-Metal Hydrid
NTC	Negative Temperature Coefficient
PBE	Plastic Bonded Electrode
PT 100	Temperature Sensor, Typ PT 100
SOC	State of Charge
VRLA	Valve Regulated Lead Acid
W	Width

4 General requirements

4.1 Definitions of the components of a battery

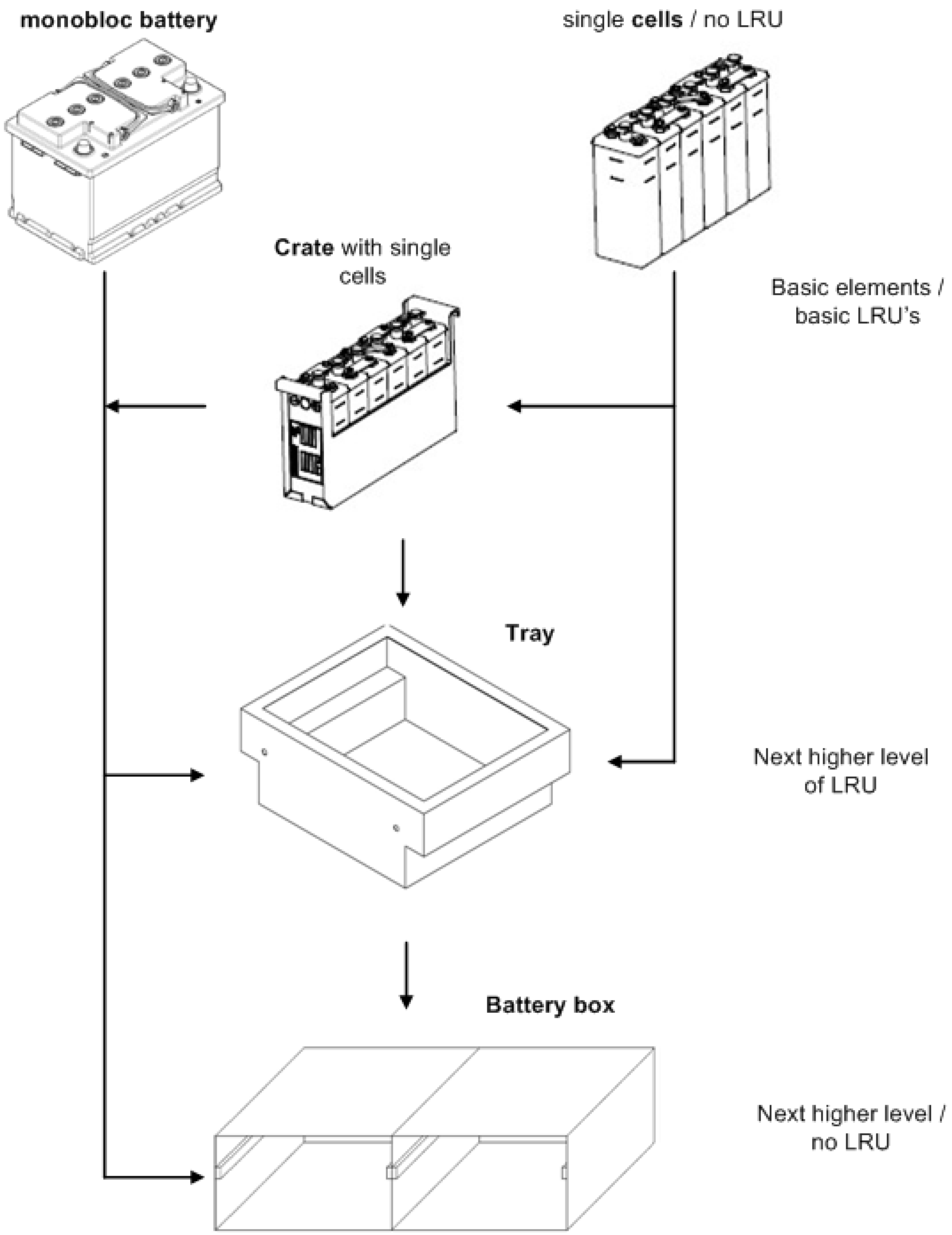


Figure 1 - Definition of cell, monobloc battery, crate, tray and box

4.2 Definitions of battery type

4.2.1 lead acid batteries

in general, called type A

4.2.2 lead acid batteries with vented technology (liquid electrolyte)

called A.1 with the sub types

- A.11 - grid plates (vented),
- A.12 - tubular positive plates (vented)

4.2.3 lead acid batteries with valve-regulated-lead technology (non-liquid respectively absorbed-liquid electrolyte)

called A.2 with the subtypes

- A.21 GEL grid plates (valve-regulated),
- A.22 GEL tubular positive plates (valve-regulated),
- A.23 - AGM grid plate (valve-regulated)

4.2.4 NiCd batteries (all with liquid electrolyte)

in general, called type B

4.2.5 NiCd batteries with fibre structure technology

called B.1 with the sub types

- B.11 - type M according to EN 60623,
- B.12 - type H according to EN 60623

4.2.6 NiCd batteries with sintered / PBE technology

called B.2 with the sub types

- B.21 - type M according to EN 60623,
- B.22 - type H according to EN 60623

NOTE NiCd pocket plate batteries can also be used under special agreement between customer and supplier.

4.3 Environmental conditions

The battery has to ensure an appropriate function at the given requirements, but with respect to life time and rechargeability the battery should not be operated above 50 °C:

- temperature class:

- ambient temperature:	T3 according to EN 50125-1. Deviations can be agreed between customer and supplier.
- transport and storage:	- 30 °C to 70 °C

- humidity: according to EN 50125-1

NOTE Battery cells and monoblocs are protected against rain, pollution, snow and hail. The battery cells / monoblocs and the battery box are protected against direct solar radiation and other heat sources.

4.4 Voltage / capacity

The preferred system voltage of the low voltage supply network has to be 110 V according to EN 50155.

The following figure shows the discharging voltage of a NiCd cell (H-Type) at different constant discharging currents (shown in multiples of C_{rt}).

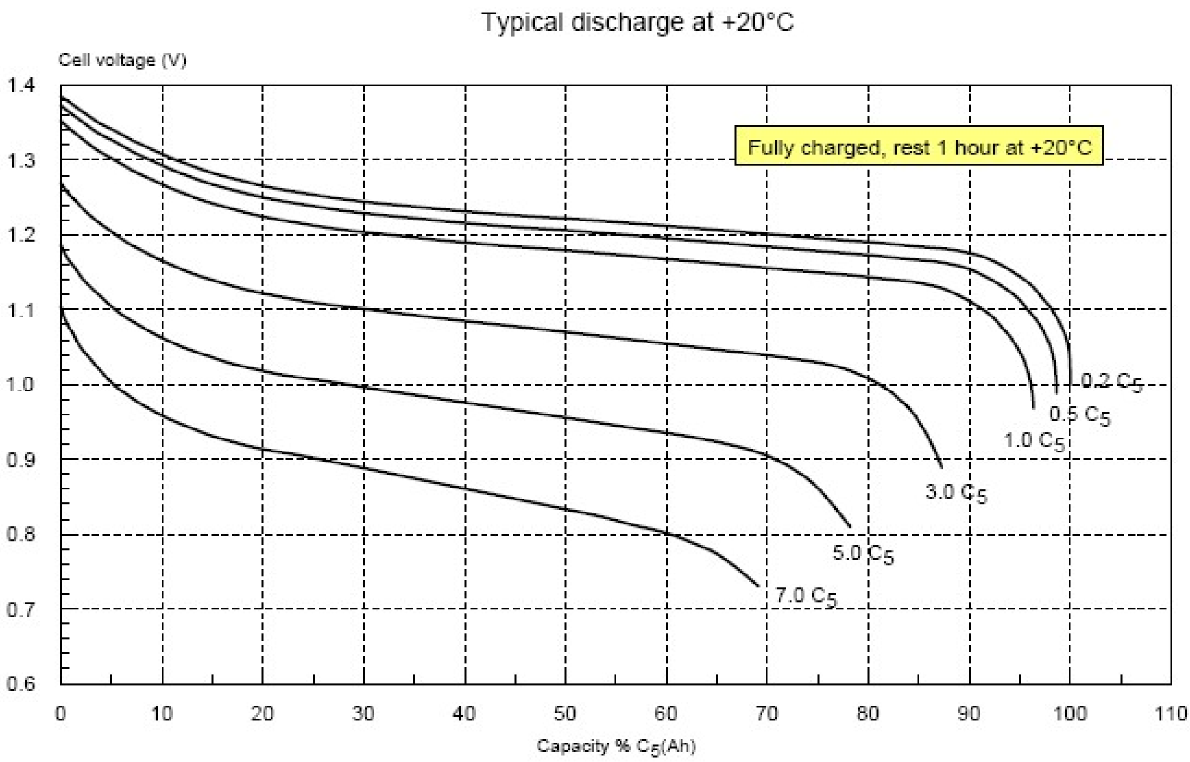


Figure 2 - Typical NiCd H-Type discharging curves at various constant discharging currents (example based on percentage of capacity)

Lead acid batteries have the same behavior, therefore the capacity of all battery types has to be specified at the 5-hour rate (C_5 according to temperature behavior in EN 60254-1 for lead acid-batteries and in EN 60623 for NiCd-Batteries).

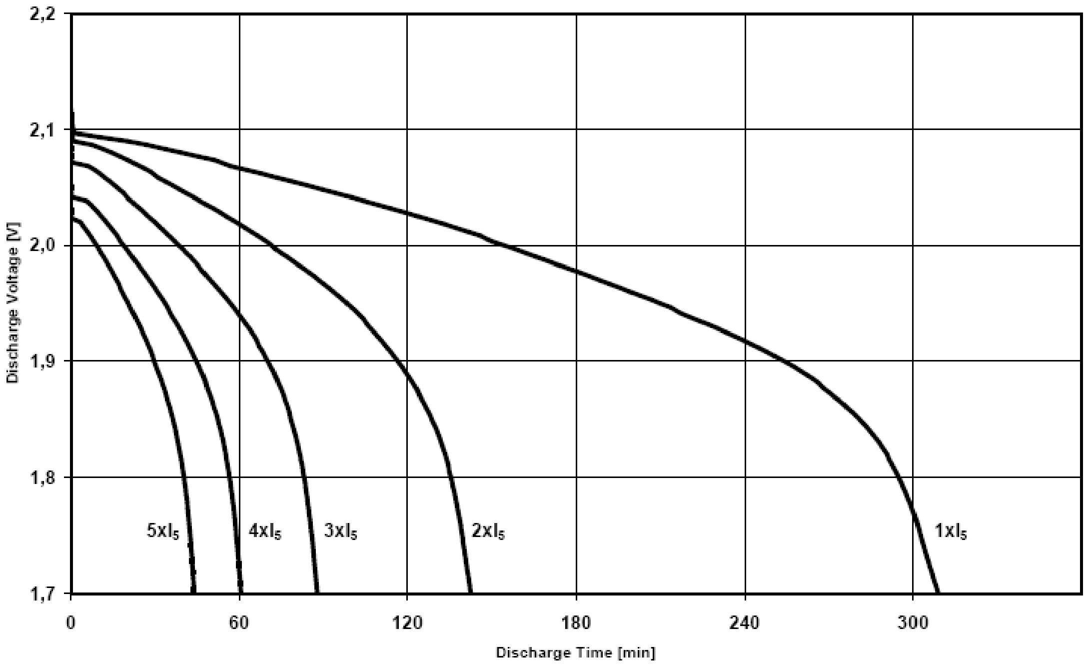


Figure 3 - VRLA Typical discharge with various currents (multiples of I5) at +20 °C (example based on discharge time)

4.5 System requirements

4.5.1 Charging requirements

The required battery charging voltage and the optimum charging method are specified according to Table 1.

Table 1 - Requirements of the charging characteristic

Normal condition	Float charge by battery charger with temperature compensation
Charging method	See 5.5 and 6.4
Steady state control accuracy of the battery charger voltage (of the ideal value at the point of voltage measurement) NOTE The accuracy refers to the voltage demand according to the ideal charging characteristic.	In case of temperature compensation ± 1,5 % Without temperature compensation ± 1 %
Charging voltage ripple	5 % (according to EN 60077-1 with disconnected battery)
Charging current ripple	See 4.7.6
Temperature compensation	See below
Detection of temperature signal from sensor	Inside battery charger

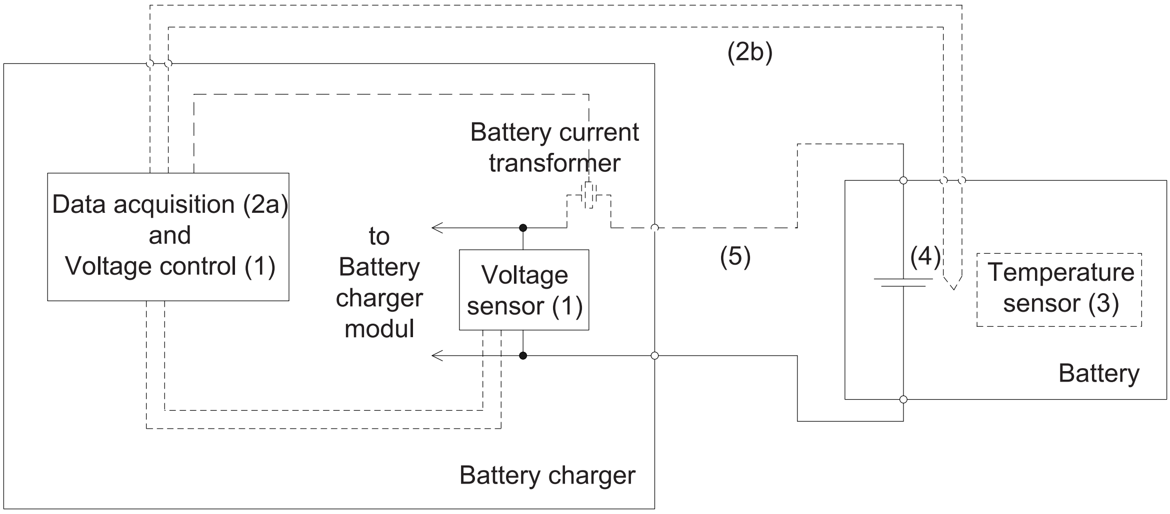


Figure 4 - Interfaces between battery and battery charger system

The interface system between battery charging system and battery consists of

1) battery voltage sensing and regulation: maximum ± 1 % (see (1) at Figure 4),
2) temperature data acquisition, (2a) at Figure 4, including wiring (2b) to the sensor: typically better than ±2,5 K (equivalent to ± 0,5 % of ideal charging voltage),
3) temperature sensor: max. tolerance ± 2 K for the specified temperature range, preferably attached to the battery, minimum one sensor per battery (see (3) in Figure 4)
   the choice of the temperature sensor shall be agreed between the system integrator and the suppliers of the battery and battery charger, in case of use of PT 100 4-cable wiring or active sensoring is necessary ; other typical sensors : 2-wire PT 1000 or NTC (10 kΩ, 25 °C),
4) position of the temperature sensor within the battery compartment (see (4) at Figure 4),
5) the cabling between battery and battery charger: part of system integration at the train (see (5) at Figure 4).

This accuracy of the charging system is to be checked:

– for a defined temperature range of less than 80

K, – at the battery charger interface.

The system integrator will check if and how the effect of the cabling needs to be compensated for.

The impact of the cabling depends on the type of temperature sensor, data acquisition system and/or location of the voltage sensor. If there is significant influence, it is possible to compensate these influences in the battery charger control system upon agreement between the system integrator and the manufacturer of the battery charger.

With the recommended temperature sensors the influence of the voltage drop on the cabling can be neglected.

4.5.2 Discharging requirements

There are different discharging requirements:

– load profile (emergency or driving operation);

– long-time discharge;

– low temperature discharging requirements;

– self discharge;

The requirements are described in the following subclauses.

4.5.2.1 Load profile

Two different types of load profiles are possible:

- emergency operation (see Figure 5);
- driving operation (see Figure 6).

Figure 7 and Figure 8 show typical load profiles for emergency operation for High Speed Trains and Regional Trains.

4.5.2.1.1 General load profiles

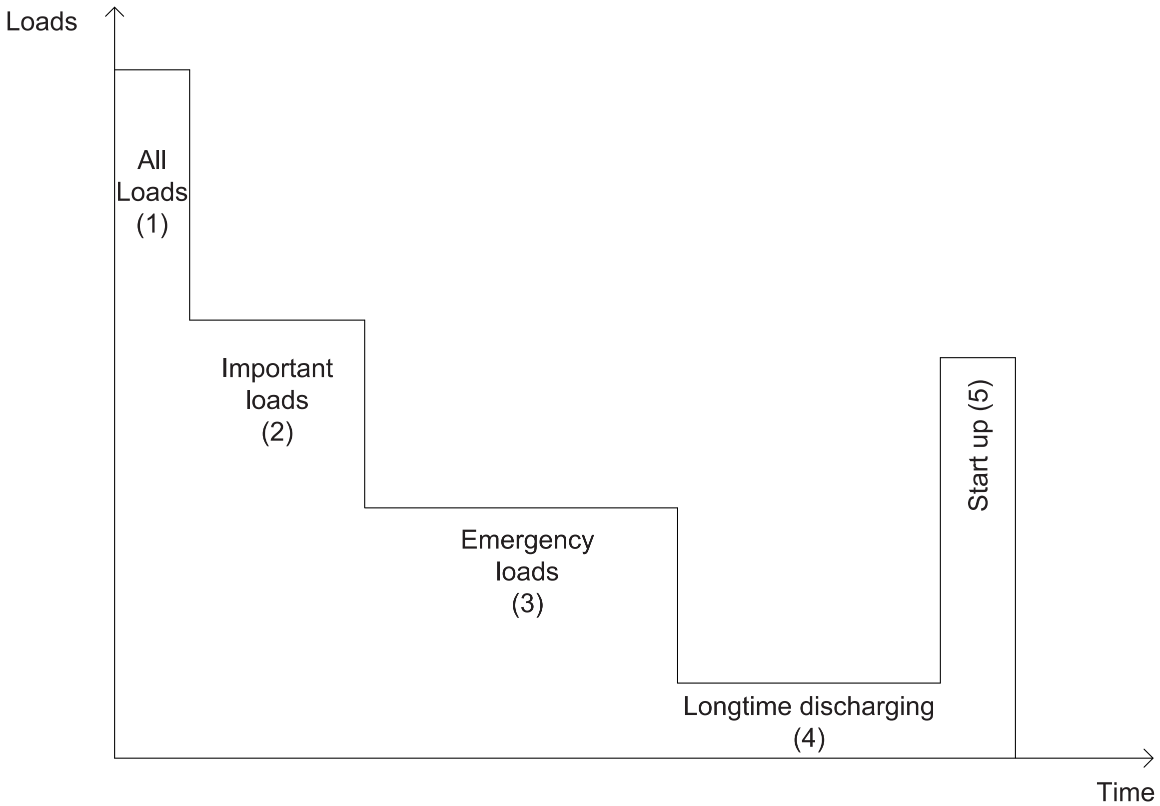


Figure 5 - Example of load profile in emergency operation (standstill of the train)

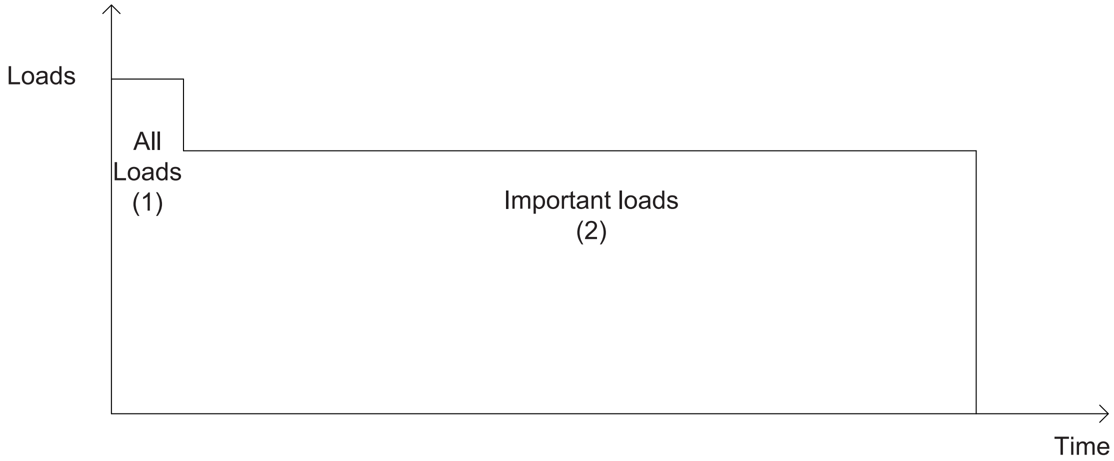


Figure 6 - Example of load profile in driving operation (driving without battery charging)

4.5.2.1.2 Typical load profiles - High speed train

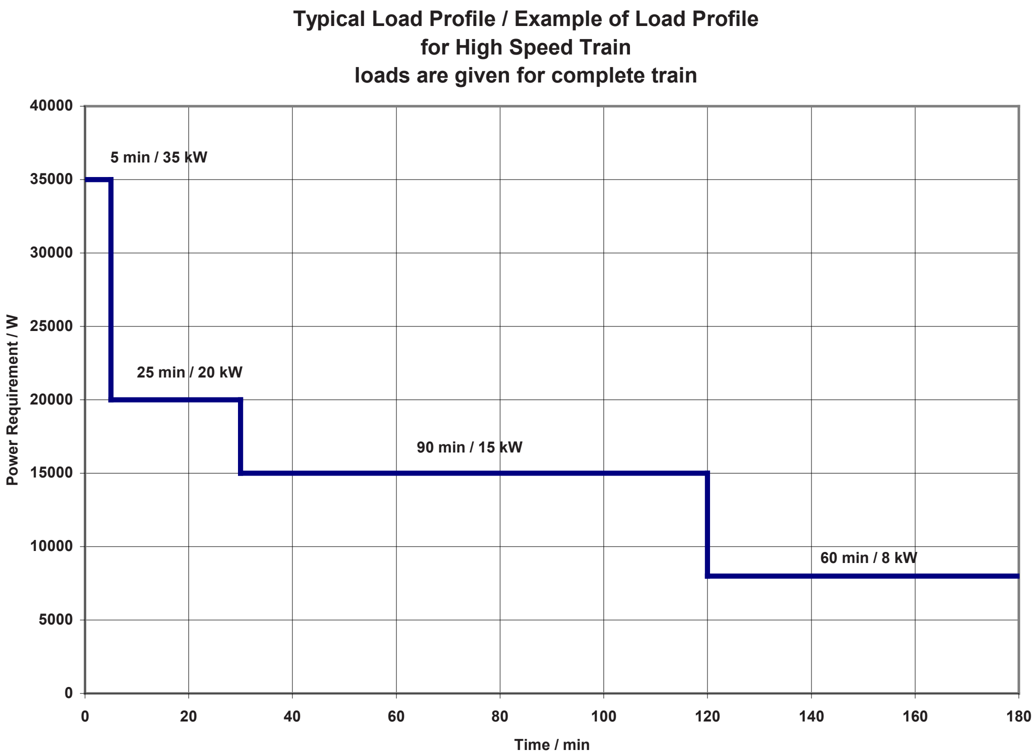


Figure 7 - Example of load profile for high speed train (without starting up segment)

4.5.2.1.3 Regional train / EMU

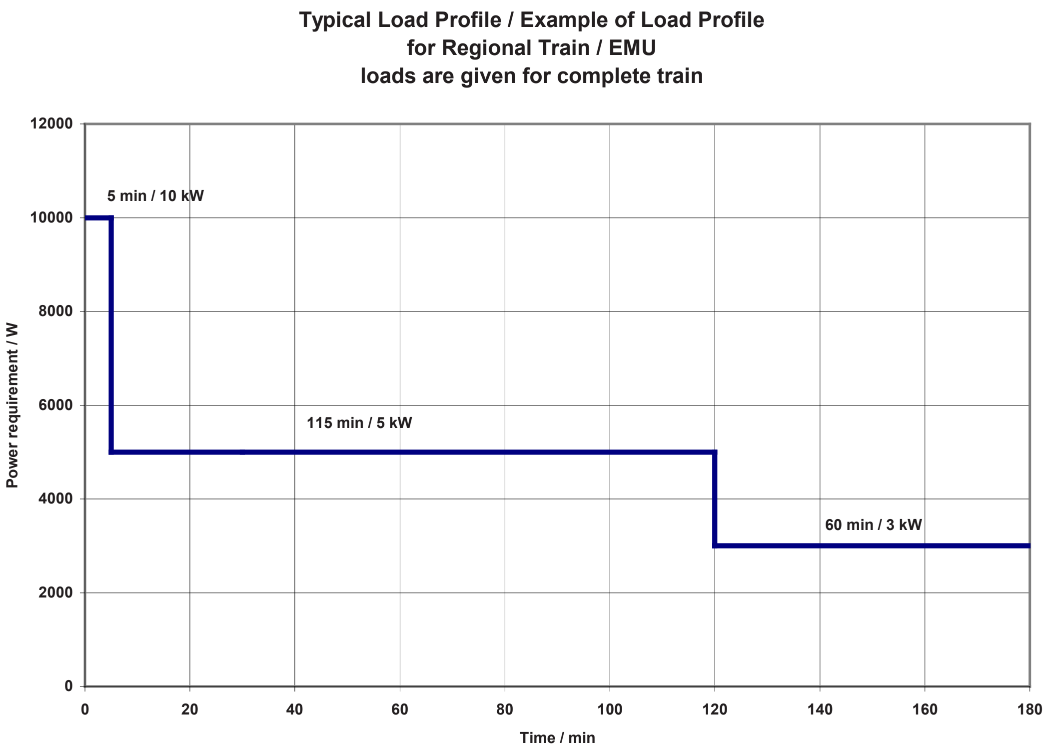


Figure 8 - Example of load profile for regional train / EMU (without starting up segment)

4.5.2.2 Long-time discharge

Long-time discharge is for example a discharging time longer than four days with a defined consumption. Such discharge cannot entirely be excluded.

NiCd-Batteries shall be able to withstand deep discharge without permanent damage (see also 4.7.3). For lead-acid batteries see 4.7.1 and 4.7.2.

4.5.2.3 Low temperature performance (if applicable)

The admissible battery temperature is -18 °C or as agreed with the customer. At this temperature, the charged battery shall still be able to supply a “deep temperature load profile” of the 110 V LVPS as specified by the customer.

In addition, no permanent damage shall occur at this temperature.

4.5.3 Charge retention (self discharge)

The reversible loss of capacity shall be maximum 3 % of the rated capacity after 30 days of storing at 20 °C for AGM and Gel lead acid types.

The reversible loss of capacity shall be maximum 5 % of the rated capacity after 30 days of storing at 20 °C for vented lead acid types.

The reversible loss of capacity shall be maximum 20 % of the rated capacity after 28 days of storing at 20 °C for NiCd-Batteries (IEC 60623). Typical values are less than 10 % reversible loss of the rated capacity after 28 days of storing at 20 °C.

For storage of batteries see 10.2.

4.5.4 Requirements for battery capacity design

Train manufacturer shall define the following parameters:

- SOC in emergency condition;
- ambient temperature in emergency condition;
- load profile (see 4.5.2.1) including energy throughput;
- minimum voltage at battery level for the whole load profile.

Battery manufacturer shall define:

- ageing factor,
- expected battery life under specified conditions.

Table 2 shows the most commonly used values.

Table 2 – Necessary information for the definition of a discharging characteristic

Type	A.11/A.21/A.23 (grid plate AGM / GEL /vented)	A.12/A.22 (tubular GEL&Vented)	B (NiCd)
State of Charge (SOC) at 20 °C under float charging conditions	up to 100 %		90 %
Suggested design temperature for whole emergency load profile (see Figure 5)	0 °C		0 °C
Load profile for low temperature performance (if applicable)	- 18 °C, see 4.5.2.3		- 18 °C, see 4.5.2.3
Ageing factor	90 %		90 %
Energy throughput (cycles x 60 % DoD)	300 to 700	1 200	2 000
Useful life expectancy at an average annual operating temperature of approximately 15 °C under railway conditions	AGM: 4 years GEL: 5 to 6 years	6 to 8 years	15 years

SOC and ageing factors shall be taken into account for battery sizing, depending on battery technology and operating conditions. The selected values are typically between 70 % and 100 %. The manufacturer shall state the expected SOC and ageing behaviour for a given specification and provide evidence of the expected battery behaviour.

4.6 Shock and vibration

Vibration and shock: see EN 61373 and 11.3.

4.7 Safety and protection requirements

The battery tray shall be with electrolyte or acid retention for cells with liquid electrolyte. Not necessary for VRLA batteries.

The vent plugs of the cells or the filling system shall be backfire-proof in order to avoid internal explosions.

The battery system shall have sufficient ventilation (no dangerous concentration of gases), calculation of ventilation shall be done according to EN 50272-2 requirements.

4.7.1 Deep discharge of lead acid batteries

Deep discharge of lead acid battery means, that more capacity (electrical energy) is discharged out of the battery than allowed, or more than defined in the discharge curves of the manufacturer, respectively. This may result in insufficient recharging.

There are different methods to protect the batteries against deep discharge. It is suggested to use parameters such as:

- voltage,
- current,
- temperature, and
- time

as a criteria for deep discharge protection. Curves showing the relationship between the current and the final discharge voltage should be available from the battery manufacturers.

4.7.2 Necessary conditions after deep discharge of lead acid batteries

Deep discharge of lead acid batteries especially without proper recharge can lead to permanent damage of the battery in terms of reduced available capacity. In case of a deep discharge the operating instructions of the battery manufacturer shall be followed.

4.7.3 Deep discharge of NiCd batteries

Deep discharge of NiCd battery means, that more capacity (electrical energy) is discharged out of the battery than allowed, or more than defined in the discharge curves of the manufacturer, respectively. The nominal final discharge voltage is 1,0 V / cell. All discharge voltages below this value at currents ≤ 1 C indicate a possible deep discharge.

4.7.4 Necessary reconditioning after deep discharge of NiCd batteries

NiCd batteries do not require specific devices to protect the battery against deep discharge itself. However, the available capacity especially after repeated deep discharge may be temporary reduced. Therefore, after a repeated deep discharge the operating instructions of the battery manufacturer shall be followed.

4.7.5 Temperature compensation

The battery charging voltage shall be temperature controlled. In practical application it has been found that following compensation factors should be used:

- NiCd batteries: - 0,003 V / K per cell
- lead acid batteries: - 0,004 V / K per cell

As a further measure the battery should not be operated in boost charging mode and changed to float charging mode above these temperatures:

- NiCd batteries: 45 °C
- lead acid batteries: 50 °C

At temperatures above 70 °C, the batteries shall be not charged.

This protects the battery at high temperatures and it also ensures the maximum possible state of charge at lower temperatures and minimises water consumption.

In case of sensor failure the system should use temporary the 20 °C charging value if not specified otherwise.

4.7.6 Protection against superimposed ripple current

The battery charging current shall be DC, as any superimposed AC component in the charging current can lead to a temperature increase of the battery. The AC content in the charging current should not exceed values as per EN 50272-2.

4.8 Fire protection

Pending the publication of an EN 45545, national fire safety standards should be met depending on the customer's specification. It may be sufficient to test according to the CEN/CLC TS 45545 series, which was published as a series of Technical Specifications before being converted into European Standards.

The acceptance of this procedure shall be agreed in advance.

NOTE Commonly, non-metallic materials are validated according to the customer specification. The fire protection can be achieved through measures on cell / monobloc and / or box level.

4.9 Maintenance

Maintenance data for preventive maintenance and corrective maintenance shall be available on request from the battery manufacturer. All data depend on the specific use at the project and type of battery and complete battery system (lead acid vented, VRLA, NiCd, monobloc batteries, cells, waterfilling system).

Following maintenance steps are necessary for the different Battery types (values and procedures depending on the project):

Table 3 - Maintenance steps for different battery types

Maintenance steps	Type of battery		
	A1	A2	B
Visual inspection	x	x	x
Topping up with demineralised water	x		x
Cleanliness battery and contacts	x	x	x
Reconditioning			x

5 Lead acid batteries

5.1 General

The preferred sizes of single cells / monobloc batteries and the charging characteristic are given in this subclause.

The following general features apply for lead acid batteries:
- VRLA - valve-regulated-lead-acid cells (vented-lead-acid types possible in special cases);
- nominal cell voltage 2,0 V;
- 54 Cells per battery independently of the technologies.

5.2 Sizes of vented batteries

Table 4 - Specification of battery sizes of vented single cells / monobloc batteries

C_5 (Ah)	Nominal voltage (V)	Dimensions L x W x H (mm x mm x mm)
	Grid plates	Monobloc
80	12,0 V	353 x 175 x 190
135	12,0 V	513 x 223 x 223
190	12,0 V	518 x 276 x 242
	Tubular plates	Cell
120	2,0 V	47 x 198 x 370
180	2,0 V	65 x 198 x 370
240	2,0 V	83 x 198 x 370
300	2,0 V	101 x 198 x 370
360	2,0 V	119 x 198 x 370
420	2,0 V	137 x 198 x 370
480	2,0 V	155 x 198 x 370
240	2,0 V	65 x 198 x 440
320	2,0 V	83 x 198 x 440
400	2,0 V	101 x 198 x 440
480	2,0 V	119 x 198 x 440
560	2,0 V	137 x 198 x 440

5.3 Sizes of GEL batteries

Table 5 - Specification of battery sizes of GEL single cells / monobloc batteries

C_5 (Ah)	Nominal voltage (V)	Dimensions L x W x H (mm x mm x mm)
	Grid plates	Monobloc
61	12,0 V	353 x 175 x 196
80	12,0 V	330 x 171 x 236
105	12,0 V	345 x 172 x 283
115	12,0 V	548 x 115 x 275
122	12,0 V	513 x 223 x 225
155	12,0 V	568 x 128 x 320
175	12,0 V	518 x 274 x 238
180	6,0 V	246 x 192 x 275
240	6,0 V	312 x 182 x 359
	Tubular plates	Cell
110	2,0 V	47 x 198 x 370
165	2,0 V	65 x 198 x 370
220	2,0 V	83 x 198 x 370
275	2,0 V	101 x 198 x 370
330	2,0 V	119 x 198 x 370
385	2,0 V	137 x 198 x 370
440	2,0 V	155 x 198 x 370
210	2,0 V	65 x 198 x 440
280	2,0 V	83 x 198 x 440
350	2,0 V	101 x 198 x 440
420	2,0 V	119 x 198 x 440
490	2,0 V	137 x 198 x 440

5.4 Sizes of AGM batteries

Table 6 - Specification of battery sizes of AGM single cells / monobloc batteries

C_5 (Ah)	Nominal voltage (V)	Dimensions L x W x H (mm x mm x mm)
	Grid plates	Monobloc / cell
80	12,0 V	395 x 125 x 275
100	12,0 V	545 x 125 x 240
110	12, 0 V	345 x 175 x 285
125	12, 0 V	520 x 225 x 230
150	12, 0 V	560 x 125 x 305
160	6,0 V	360 x 175 x 230
170	6,0 V	245 x 190 x 275
195	6,0 V	375 x 135 x 250
220	6,0 V	315 x 190 x 275
260	2,0 V	210 x 135 x 265
375	2,0 V	180 x 155 x 315
410	2,0 V	210 x 205 x 265

5.5 Charging characteristic

Charge characteristics are to be selected in a way to ensure high state of charge under normal operating conditions, and lowest possible water consumption (for vented systems).

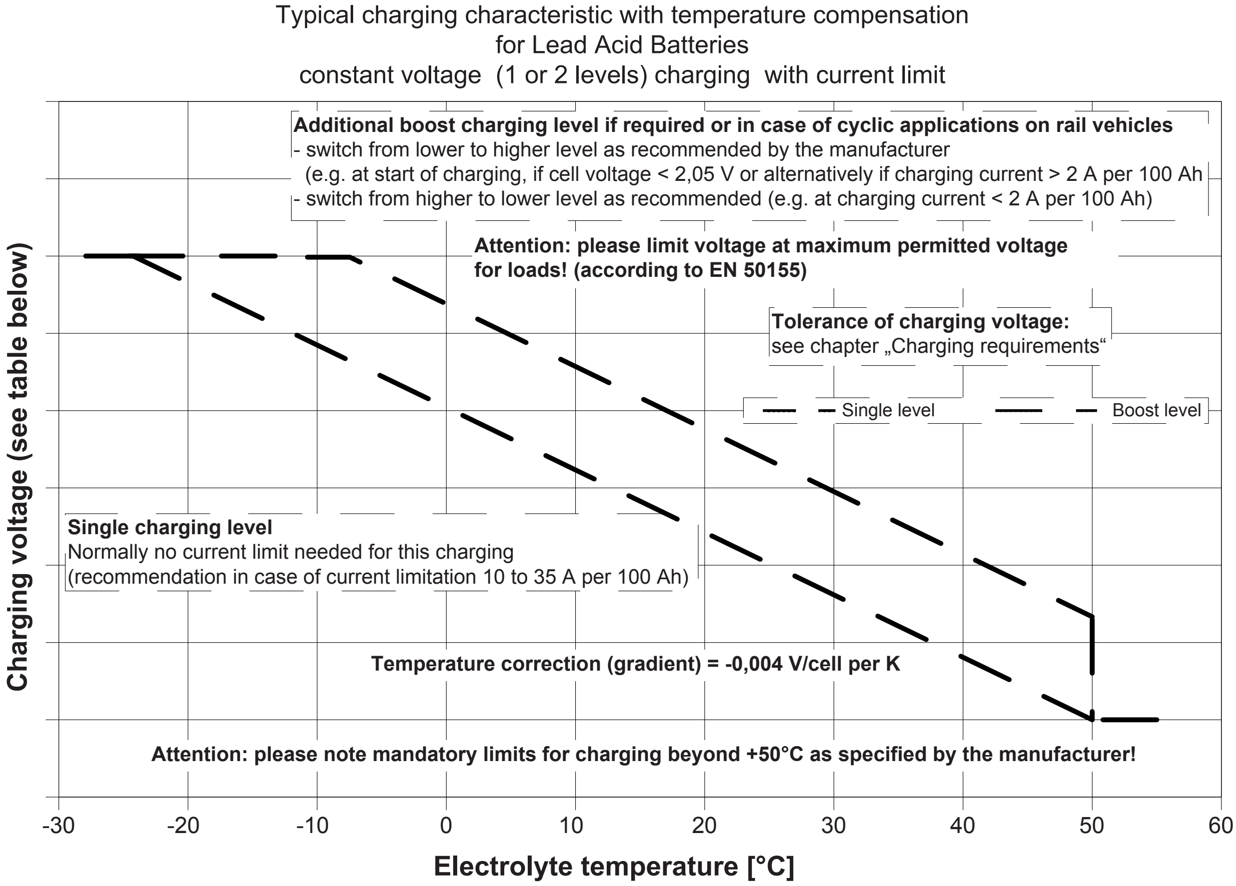


Figure 9 - Typical charging curves for lead acid batteries on rail vehicles over temperature

Table 7 - Typical charging voltages for lead acid batteries on rail vehicles

Lead acid technology	Vented	VRLA		Remarks
		Gel	AGM	
Charging with single level				
Charging voltage at +20°C	2,32 -2,38 V/cell	2,32 -2,38 V/cell	2,27 -2,32 V/cell	See solid line at Figure 9 ——— ———
	Temperature correction -0,004 V /°K			
In case of additional boost level				
Charging voltage at +20 °C	2,39 V/cell	2,39 V/cell	2,35 V/cell	See dotted line Figure 9 - - - - - - - - - - - - - -
	Temperature correction -0,004 V /°K			
NOTE 1 For further settings and limits please refer to the typical charging curves above in Figure 9.				
NOTE 2 Voltages to be multiplied for 110 V-Systems: typically 54 single cells, 18 blocs each 3 cells or 9 blocs each 6 cells.				

6 NiCd batteries

6.1 General

Preferred tray dimensions, mounting interface and the charging characteristic are given in this subclause.

Following general requirements for NiCd batteries recommended:

- graphite free cells (for other cells which contain graphite see 3.1),
- nominal cell voltage 1,2 V,
- 76-86 cells per battery (DC 110 V systems) depending on the technologies.

6.2 Preferred tray dimensions and mounting interface

This is valid for the dimensioning of NiCd-Batteries.

6.3 Preconditions for the design of the battery tray

The preconditions for the design of the battery tray are:

- width W battery tray 800 mm,
- height H battery tray 400 mm,
- length A in steps, depending on battery size (see Table 8).

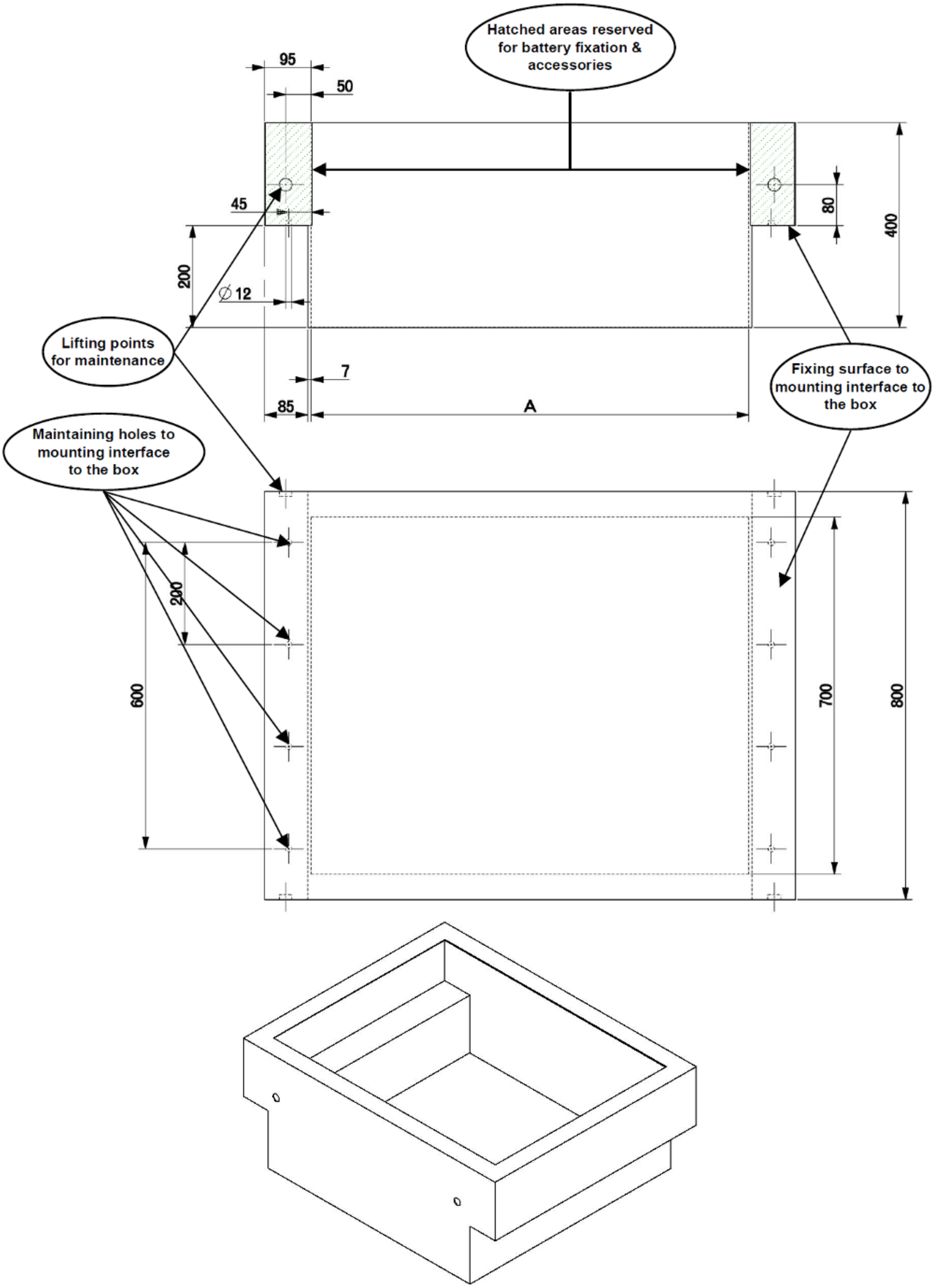


Figure 10 - Typical mounting interface dimensions including fixing interfaces

Table 8 - Specification of battery inner tray length ("A" reference in Figure 10)

Standard preferred dimensions	Battery inner tray length A (mm)
1	550
2	630
3	790
4	857
5	973
6	1 024
7	1 136
8	1 260
9	1 400
10	1 570
11	1 626

For examples of fixing mechanism for defined NiCd battery trays see 7.2

6.4 Charging characteristic

Charge characteristics are to be selected in a way to ensure high state of charge under normal operating conditions, and lowest possible water consumption (for vented systems).

NiCd cells can be charged with a charging current of 1,5 x I_5 = 0,3 x C_{rt}, with single or dual level, constant voltage as per the following table:

Table 9 - NiCd batteries charging characteristics

NiCd batteries charging characteristics		Fibre technology				Sinter/PBE technology	
	Parameter	Perfor-mance type L	Perfor-mance type M	Perfor-mance type H	Perfor-mance type X	All Perfor-mance types	Remarks
Basic data for 1 level charging	Float charging voltage at 20 °C	1,58 V / cell	1,53 V / cell	1,47 V / cell	1,45 V / cell	1,47 V / cell	See point ① on Figure 11
Basic data for 2 levels charging	Float charging voltage at 20 °C	1,55 V / cell	1,50 V / cell	1,45 V / cell	1,40 V / cell	1,47 V / cell	See point ① on Figure 11
	Temperature correction	-0,003V/°K / cell					See Figure 11
	Boost charging voltage at 20 °C	1,65 V/cell	1,60 V/cell	1,55 V/cell	1,50 V/cell	None	See point ② on Figure 11
Switching setpoints (all charge modes)	Mandatory, change from boost to float charging	45 °C					See point ③ on Figure 11
	Mandatory stop charging of battery	70 °C					See point ④ on Figure 11
	Maximum voltage limitation at low temperature as per EN 50155 voltage window	137,5 V or lower for total battery, value per cell according to number of cells per battery					See point ⑤ on Figure 11
	Standard, from boost to float charging	I < 0,05 C				None	Current measurement necessary
	Standard, from float to boost charging	I > 0,05 C				None	Current measurement necessary

A temperature compensation of -0,003V/°K/cell is requested, with possible limitation at low temperature to remain in EN 50155 voltage window (according to number of cells in the battery). Temperature where this condition occurs depends on sizing and application parameters.

The typical charging voltage for most applications is as shown per cell, temperature compensated. Higher or lower values, within the above limits, can be selected depending on sizing and application parameters.

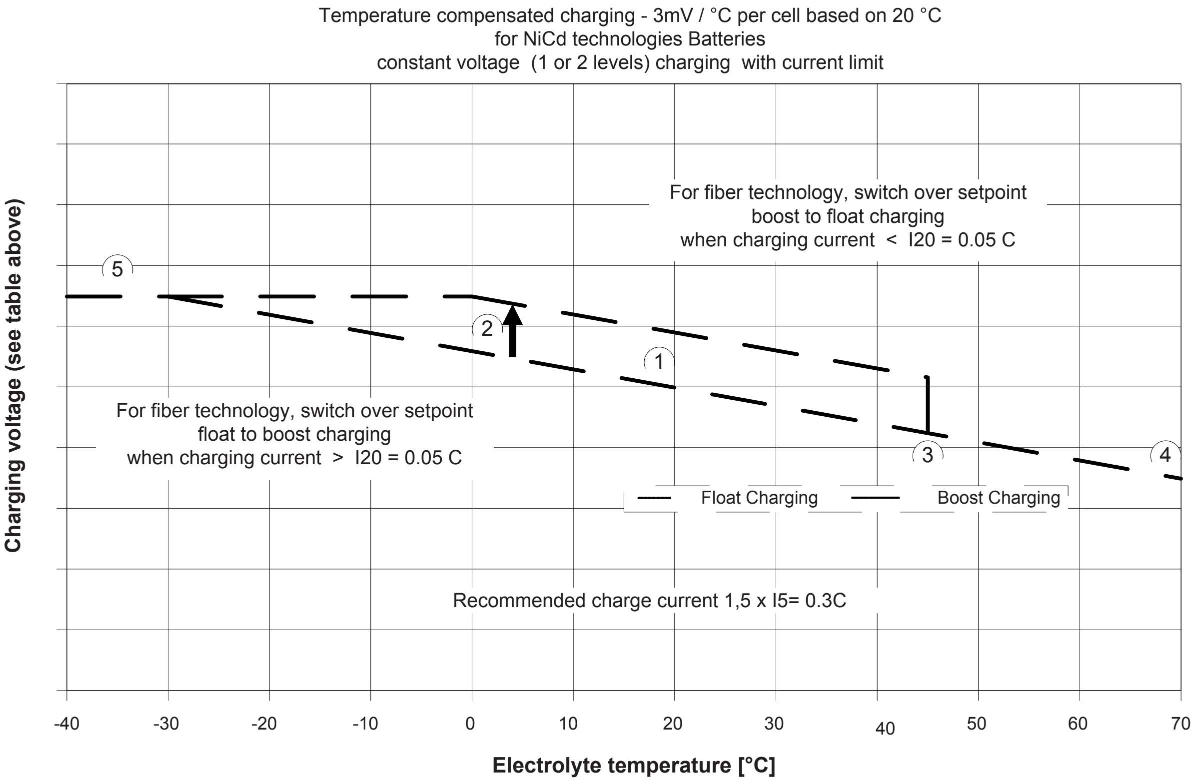


Figure 11 - Typical charging characteristic of NiCd-batteries

7 Proposal for mechanical design of Lead Acid and NiCd Batteries

7.1 General

Three general items distinguish the mechanical design of a battery system:

- fixing mechanism;
- accessibility;
- location of battery.

7.2 Fixing mechanism

Three kinds of fixing mechanism of battery equipment can be designed:

- fix
  assembly bolted;
- roll
  with rollers for accessing the tray or crate;
- slide
  with slides for accessing the tray or crate.

7.2.1 Fixed solution

The batteries are installed fixed (bolted). Two solutions are applicable:

- without tray (especially for monobloc batteries), see Figure 12;
- with tray (for all type of batteries, cell or monobloc batteries), see Figure 13.

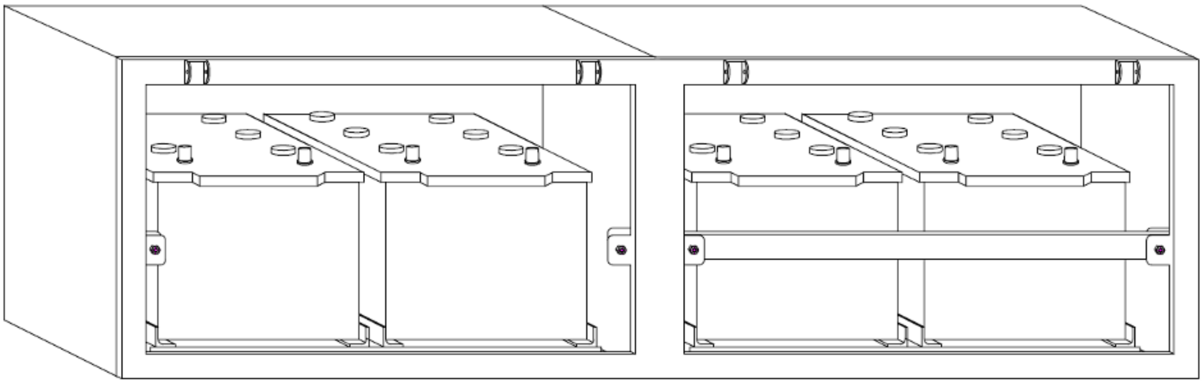


Figure 12 - Example of fixed solution without tray

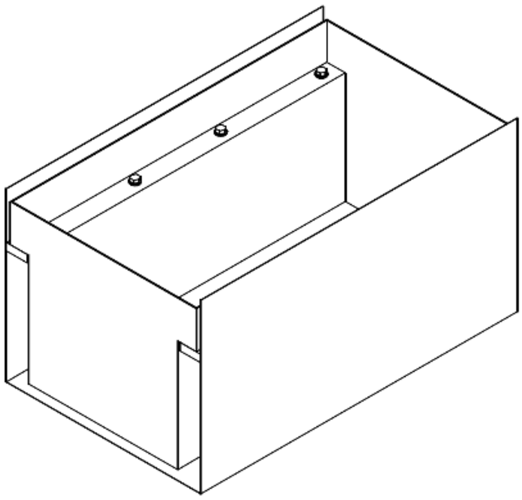


Figure 13 - Example of fixed solution with tray

7.2.2 Roll solution

The batteries are installed in trays with rollers. Two solutions are practicable:

– with folding beams (rollers on the tray), see Figure 14;

– with roller bearings (rollers on the box), see Figure 15.

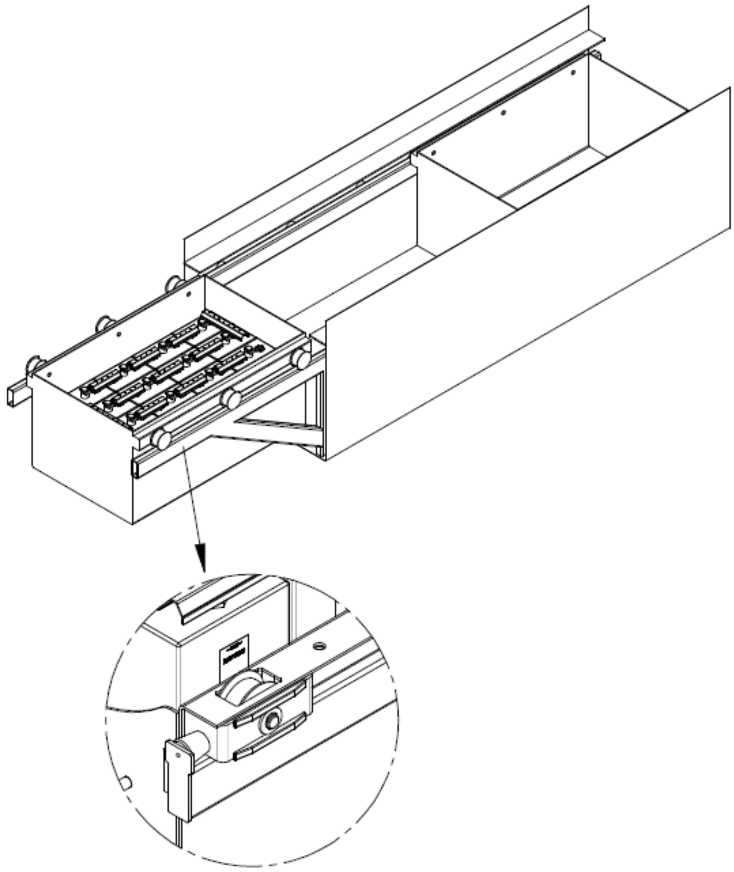


Figure 14 - Example of roll solution with folding beams

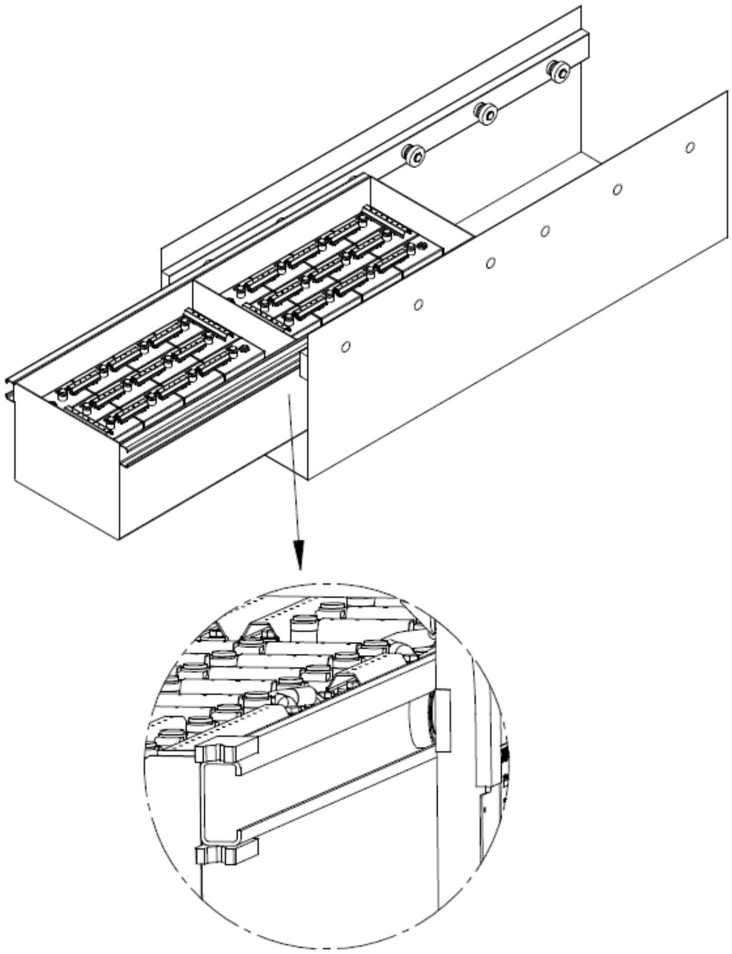


Figure 15 - Example of roll solution with roller bearings

7.2.3 Slide solution

The batteries are installed in trays with telescope sliders, see Figure 16.

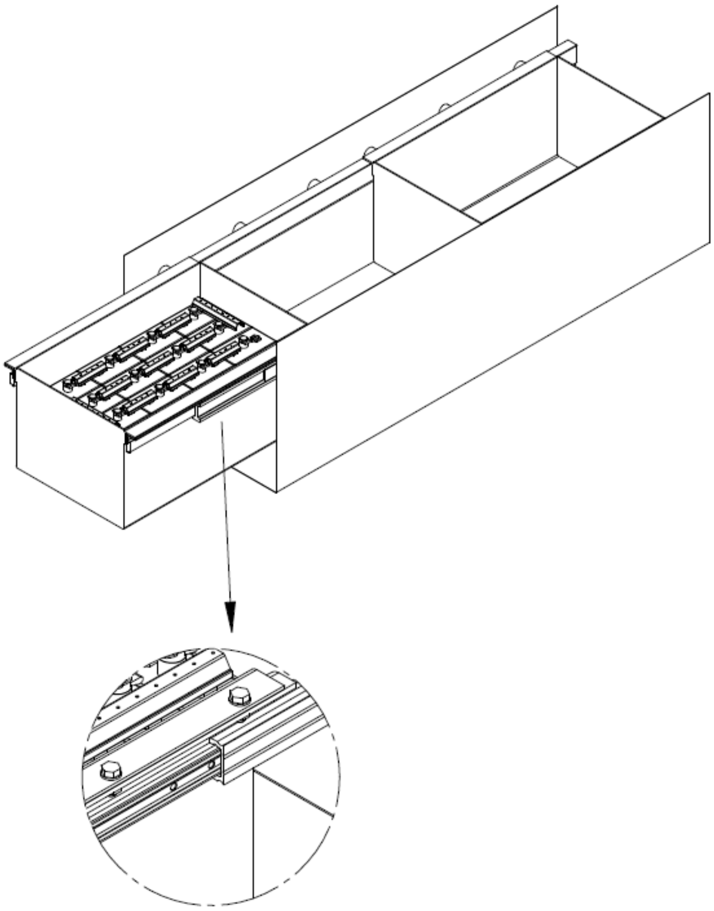


Figure 16 - Example of slide solution

7.3 Accessibility

Three kinds of accessibility of batteries are possible:

- top (accessibility from the top)
  mounting on the roof or inside the carbody;
- side (accessibility from one side)
  mounting under the carbody or inside the carbody;
- across (accessibility from both sides)
  mounting under the carbody.

7.4 Location of battery

Three locations of battery at rolling stock are possible:

- on the roof;
- inside the carbody (cabinets, racks);
- underfloor (low floor, high floor trains).

7.5 Ventilation of battery box

To avoid an explosion of detonating gas inside the battery box sufficient ventilation will be necessary. The air inlet and outlet openings shall be arranged in a way, that a flow through will be possible, also during standstill of the vehicle e.g. in the depot.

The location of the openings on the box depends of the specific situation of the box installation on the vehicle.

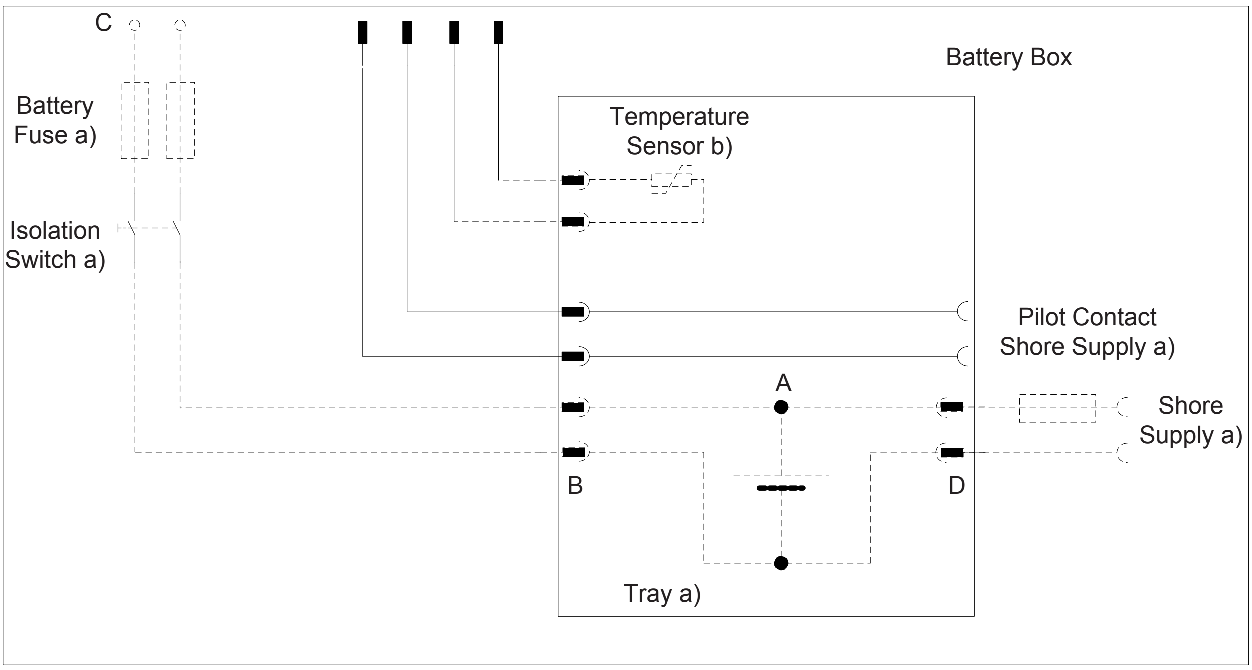
Natural ventilation is to be preferred.

Regarding the dimensions of the openings and other requirements, please refer to EN 50272-2 and follow the national authority rules, if applicable.

8 Electric interface

8.1 General

Following general electric interfaces are shown. Not all parts are necessary at different battery systems. This depends on the project.



Key
A - Battery terminal (cell or monobloc)
B - Tray terminal
C - Main terminal (complete battery system)
D - Shore supply connector (also possible mounting direct on the tray)
a) - if applicable
b) - Preferred inside the tray, also possible mounting direct on the box

Figure 17 - Schematic of a battery system (not all parts are necessary at all battery systems)

8.2 Electrical connections

Different designs may be used depending on the detailed battery construction and the requirements of the train manufacturer:

- the design of the main terminal (interface between the train on-board-system and the battery) depends on the project requirements and has to be agreed between the customer and manufacturer. It is possible to use bolted connection or plug-in connectors (similar to the shore supply);
- the size of the terminal cables of different lengths depend on the project and have to be agreed between the customer and manufacturer;
- plug-in connector for battery workshop supply or connecting tray and box;
- plug-in connector for sensing (temperature sensor, pilot contact for workshop supply etc.) see EN 50467 *Railway applications - Rolling stock - Electrical connectors, requirements and test method*;
- the battery shall be designed in a way that the positive and negative battery main terminals cannot be mixed up.

9 Marking

9.1 Safety signs

9.1.1 Outside the box

As a minimum, the following safety signs shall be placed outside the box:

- Warning signs (according to EN ISO 7010):
  - W012 - Warning; Electricity
  - W026 - Warning; Battery Charging
- Prohibition sign (according to EN ISO 7010):
  - P003 - No open flame; Fire, open ignition source and smoking prohibited.

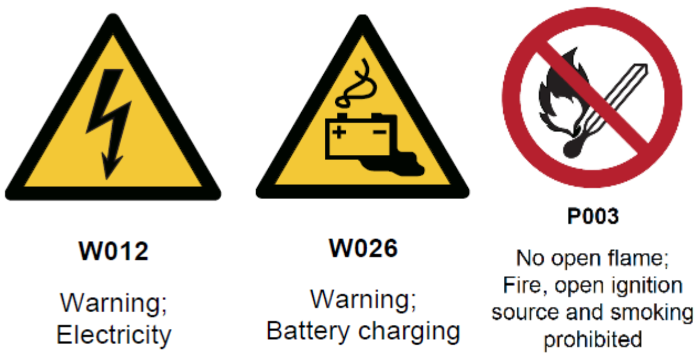


Figure 18 – Safety signs outside the battery box

9.1.2 Tray, crate or other places inside the box

The following safety signs shall be placed inside the box:

- Warning signs (according to EN ISO 7010):

  - W012 - Warning; Electricity
  - W026 - Warning; Battery Charging
  - W023 - Warning; Corrosive substance
  - W002 – Warning; Explosive material
- Prohibition sign (according to EN ISO 7010):
  - P003 - No open flame; Fire, open ignition source and smoking prohibited
- Mandatory action signs (according to EN ISO 7010):
  - M002 – Refer to instruction manual/booklet
  - M004 – Wear eye protection
  - M009 – Wear protective gloves
  - M010 – Wear protective clothing

If the safety signs are fixed on the tray or crate, the signs can be in black and white or colour.

W012

Warning;
Electricity

W026

Warning;
Battery charging

W023

Warning;
Corrosive substance

W002

Warning;
Explosive material

P003

No open flame;
Fire, open ignition
source and smoking
prohibited

M002

Refer to instruction
manual/booklet

M004

Wear eye protection

M009

Wear protective
gloves

M010

Wear protective
clothing

Figure 19 – Safety signs inside the battery box

9.1.3 Cells or monoblocs

The marking of cell or monobloc batteries shall comply with:

- EN 60896-11, EN 60896-21 and EN 60254-2 for lead acid batteries,
- EN 60623 for NiCd batteries.

9.2 Nameplate

9.2.1 Box

The nameplate of the box shall include the following information:

- serial number;
- part number;
- weight;
- revision level (if applicable);
- name of manufacturer.

9.2.2 Tray, crate or other nameplates inside the box

The nameplate tray, crate or other nameplates inside the box shall comply with EN 50272-3.

In case of multiple trays, the number and position of trays shall be given.

9.2.3 Cells or monoblocs

The nameplate of cell or monobloc batteries shall comply with:

- EN 60896-11, EN 60896-21 and EN 60254-2 for lead acid batteries,
- EN 60623 for NiCd batteries.

10 Storage and transportation conditions

10.1 Transportation

According to EN 50272-2 or the valid regulations of the respective country and the battery manual. This should accompany the batteries.

10.2 Storage of batteries

For storage, batteries shall be placed in a frost-free, dry room. The battery shall not be exposed to direct sunlight.

For NiCd batteries:

as a recommendation for long term storage (longer than three months without charging), graphitfree NiCd Batteries (Type B1 and B2 see 4.2.5 and 4.2.6) should be stored discharged. For further details, please refer to the battery manual. The battery manufacturer has to specify the method of storage in his manual.

For lead acid batteries:

in order to protect the battery, the battery shall be recharged in regular intervals. For VRLA batteries this can be up to twelve months. The battery manufacturer has to specify the charging methods and intervals to be applied. For further details, please refer to the battery manual. The battery manufacturer has to specify the method of storage in his manual.

11 Testing

11.1 General

The aim of the tests is to prove conformity with the relevant specification. It is recommended that the number of expensive tests is limited to those that are necessary for validation of the product. Nevertheless, special requirements of railway environment have to be taken into account.

The test procedure and the test parameters shall be specified by agreement between the manufacturer and the customer.

There are the following categories of tests:

- type test;
- routine test.

Table 10 - List of tests

Nature of test	Type test	Routine test
Tests according to EN 60896-11 and EN 60896-21 for lead acid batteries	According to EN 60896-11 and EN 60896-21	According to EN 60896-11 and EN 60896-21
Tests according to EN 60623 for NiCd-batteries	According to EN 60623	According to EN 60623
Shock and vibration	(see 11.3)	
Load profile test (load profile according to Annex B)	See A.5	

It is recommended to agree on suitable tests between the manufacturer and the customer.

11.2 Routine test

A routine test is performed in order to verify the quality of a batch of delivered batteries / cells. The batch acceptance tests shall be based on following standards:

- battery Type A1: EN 60896-11;
- battery Type A2: EN 60896-21.

As described in these standards, there are different tests, which shall be chosen by the customer in accordance with the supplier.

Battery Type B: EN 60623 defines the requirements for serial testing.

The number of samples to be tested in a routine test shall be determined according to IEC 60410 or as agreed with the customer.

11.3 Shock and vibration

The battery, when supported at its designed fixings, shall be able to withstand vibration and shock as stated in EN 61373.

The smallest test object is the battery cell or a monobloc. It shall be tested according to EN 61373, category 1, class B under its normal fixing conditions and working orientation.

Acceptance criterion: according to EN 61373.

For the supply of complete battery assemblies (systems), a shock and vibration test can be agreed between the manufacturer and user. In case of no shock and vibration test on the complete battery assembly a FEM stability calculation shall be provided by the manufacturer.

In case testing has been already carried out on similar cells, monoblocs or complete battery of same technology, same manufacturer and same type of assembly, it will not be necessary to do the test again. It may be also agreed between the manufacturer and the customer to use cells and monoblocs of known and proven design without testing.

Annex A
(informative)

Load profile verification

A.1 General

This annex is applicable for the specification and verification of battery aptitude to supply requested load profiles, if specified by the customer. The aim is to control conformity of design and later of realisation with the relevant specification. It is recommended that the number of tests is limited to those which are proven to be necessary.

NOTE A load profile and the operating conditions may be optimised during the project.

A.2 General methodology

The procedure and the parameters shall be specified by agreement between the battery manufacturer and the customer including:

- cumulated discharged energy vs. load profile,
- power available vs. load profile.

In addition, the realistic train operation has to be taken into account:

- environment (e.g. temperature), and
- operational requirements (e.g. minimum voltage).

An important part is the charge level of the battery and its ageing, as mentioned in Table 2.

This process requires a well defined and harmonised methodology for specification and verification of the load profile compliance. The selected approach has two steps:

- simulation by calculation or testing of the compliance of the battery vs. load profile of the train, for one or several specific load profiles over a defined environment (temperature) under defined operational conditions (voltages);
- measurements on real battery for the verification of the compliance vs. load profile shall be realised under simulation conditions.

Profiles shall be initially requested by the operator or by the train system integrator, including adjustments to take into account final release of architecture and equipments installed on the train.

In case several profiles are requested, all load profiles shall be calculated or tested. Each battery manufacturer shall provide to the customer his sizings for all requested load profiles in the tendering phase. Those sizings shall be available for the operator on request. If acceptable by the customer it may be sufficient to do the worst case only.

A.3 Sizing description (calculation, simulation or preliminary tests)

The battery sizing shall be done by the battery manufacturer, in order to make sure that the required profile will be met in all identified discharge conditions agreed (e.g. environment, sizing factors for charge or ageing). This can be done through numerical calculation (e.g. simulation) or laboratory testing – or both in case numerical calculation is not considered precise enough.

A.4 Sizing documentation

The results of the calculations and simulations shall be documented in a report. The minimum requirements for the contents of the report are:

- key data for the battery: technology, type, capacity & quantity of cells for the whole train, electrical architecture as defined by the train system integrator,
- description of the battery behaviour over discharge time, with indication of compliance vs. requested conditions (e.g. minimum voltage) for each profile segment in their occurrence order,
- environmental conditions (e.g. temperatures for charging, discharging) and derating factors (e.g. ageing, initial SOC depending on charging condition).

A.5 Operational verification (load profile test)

As the main concept of this standard is to allow for interchangeability of batteries, it is essential that the final design data document (initial or updated) is filed:

- load profile test to be realised as defined in agreement between operator, train system integrator and cell or battery manufacturer;
- test temperature corresponding to selected sizing;
- minimum representative quantity of cells or monoblocs (typically over 10% of the total cell quantity connected in series respectively a corresponding number of monoblocs): in case paralleling profile will be adjusted proportionally, in representative arrangement of cells. This will be referred later on as “battery” for the testing purposes.

The following tolerances are admitted:

- ambient temperature: ± 2 K;
- cells temperature dispersion in the battery: ± 2 K (not applicable for monoblocs).

Battery preparation:

- cells or battery could be submitted to a suitable number of pre-activation cycles;
- complete charge as per EN 60896-11 / EN 60896-21 / EN 60254-1 / EN 60623;
- application of the derating factors as mentioned in agreed simulation / calculation / lab. testing stage, through partial discharge in relation to the rated capacity C_{rt} (e.g. 90 % ageing and 90 % SOC => 90 %x90 %=81 % initial situation, thus 19 % partial discharge);
- cells or battery should then immediately be installed to reach temperature situation (agreed temperature), until stable temperature is obtained.

Profile should then be realised as mentioned in agreed simulation / calculation / lab. testing stage, and all load profile parameters (time, voltage, current, temperature) should be recorded.

The test plan shall be agreed prior to the tests. This plan especially contains:

- the conditions for preparation,
- the conditions for the specific test,
- the scaling factor if needed (number of representative cells).

Acceptance criterion: compliance with minimum voltage (depending on battery type).

A.6 Test report

The results of the verification measurements shall be documented in a report. The minimum requirements for the contents of the report are:

- key data for the battery: technology, type, capacity and quantity of cells for the whole train, electrical architecture,
- description of the battery behaviour over discharge time, with indication of compliance vs. requested conditions (e.g. minimum voltage) for each profile segment in their occurrence order,
- environmental conditions (e.g. temperatures) and de-rating factors (e.g. ageing, initial SOC of tested battery),
- description of the measurement equipment used, with calibration certificates,
- any observations during the tests which might have an effect on the interpretation of the test results.

In case of scaling, it might be necessary to apply a factor to compare test to the load profile. This should then be clearly mentioned.

Annex B
(informative)

Example of functions during load profile

The following table give examples of functions that may be supplied by the battery during different steps of the load profile (see also 4.5.2.1). As a preparation, an agreement between the operator and the train system integrator for the supplied functions during the different load profile steps is necessary.

Table B.1 – Examples of functions during different steps of load profile

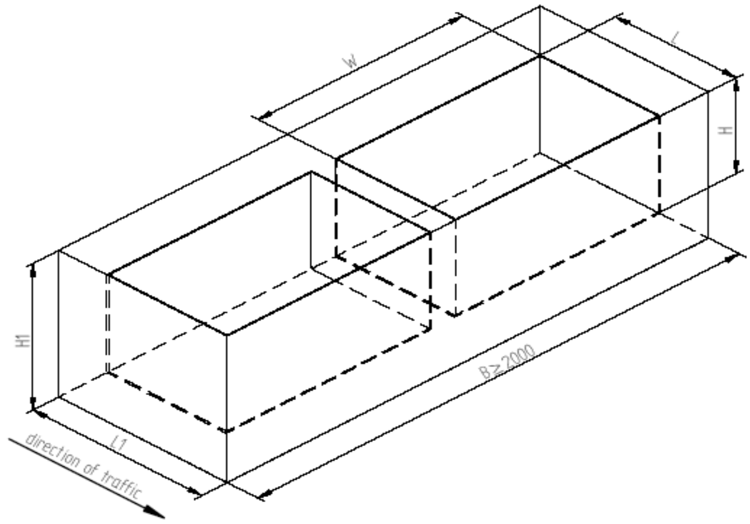
	Load profile for emergency operation (see 4.5.2.1.1, Figure 5)					Load profile without battery charger in driving operation (see 4.5.2.1.1, Figure 6)		Others (e.g. maintenance)
Function	1	2	3	4	5	1	2	
Brake control	☐	☐	☐	☐	☐	☐	☐	☐
Train control system	☐	☐	☐	☐	☐	☐	☐	☐
Train control monitoring system	☐	☐	☐	☐	☐	☐	☐	☐
Tail lights	☐	☐	☐	☐	☐	☐	☐	☐
Head lights	☐	☐	☐	☐	☐	☐	☐	☐
Marker lights	☐	☐	☐	☐	☐	☐	☐	☐
Passenger lighting	☐	☐	☐	☐	☐	☐	☐	☐
Passenger lighting reduced	☐	☐	☐	☐	☐	☐	☐	☐
Passenger lighting emergency	☐	☐	☐	☐	☐	☐	☐	☐
Cab lighting	☐	☐	☐	☐	☐	☐	☐	☐
Traction converter control	☐	☐	☐	☐	☐	☐	☐	☐
Auxiliary converter control	☐	☐	☐	☐	☐	☐	☐	☐
Train Radio	☐	☐	☐	☐	☐	☐	☐	☐
Internal train communication	☐	☐	☐	☐	☐	☐	☐	☐
Pantograph	☐	☐	☐	☐	☐	☐	☐	☐
Doors	☐	☐	☐	☐	☐	☐	☐	☐
Toilet control	☐	☐	☐	☐	☐	☐	☐	☐
CCTV	☐	☐	☐	☐	☐	☐	☐	☐
Passenger information system (normal state)	☐	☐	☐	☐	☐	☐	☐	☐
Passenger information system (emergency state)	☐	☐	☐	☐	☐	☐	☐	☐
HVAC Drivers Cab control	☐	☐	☐	☐	☐	☐	☐	☐
HVAC Passenger Compartment control	☐	☐	☐	☐	☐	☐	☐	☐
Emergency ventilation	☐	☐	☐	☐	☐	☐	☐	☐
Main Compressor control	☐	☐	☐	☐	☐	☐	☐	☐
Auxiliary Compressor	☐	☐	☐	☐	☐	☐	☐	☐
Coupler defrosting heaters	☐	☐	☐	☐	☐	☐	☐	☐
Displays	☐	☐	☐	☐	☐	☐	☐	☐
Others …	☐	☐	☐	☐	☐	☐	☐	☐

Annex C
(informative)

NiCd-battery sizing for specific load profiles

Table C.1 - Specification of battery tray sizes NiCd-batteries based on given load profiles)

Example	*Type (see* 4.2.4, 4.2.5 *and* 4.2.6), *capacity and number of cells per battery set*	Battery sets per train	Battery tray length (inside) L (mm)	Total number of trays per train	Battery tray width (inside) x height W x H (mm²)
HST (see Figure 7) at 0 °C	Type B.21 145 Ah / 84 cells	4	857 (two trays in series per battery set)	8	700 x 400
	Type B 11 150 Ah / 80 cells				
	Type B 12 145 Ah / 80 cells				
HST (see Figure 7) at -18 °C	Type B.21 160 Ah / 82 cells	4	973 (two trays in series per battery set)	8	700 x 400
	Type B 11 175 Ah / 80 cells				
	Type B 12 170 Ah / 80 cells				
EMU (see Figure 8) at 0 °C	Type B.21 100 Ah / 80 cells	2	629 (two trays in series per battery set)	4	700 x 400
	Type B 11 100 Ah / 80 cells				
	Type B 12 / 90 Ah / 80 cells				
EMU (see Figure 8) - 18 °C	Type B.21 / 100 Ah / 82 cells	2	789 (two trays in series per battery set)	4	700 x 400
	Type B 11 110 Ah / 80 cells				
	Type B 12 / 110 Ah / 80 cells				



Key

L	length of battery tray
W	width of battery tray
H	height of battery tray
H1	height of battey box
L1	length of battery box
B	width of battery box

Figure C.1 - Envelope of the battery box and battery tray

A battery box can consists of one, two or four battery trays. The dimensions of the battery box have to be agreed between the customer and manufacturer.

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EN 45545-2	Railway applications - Fire protection of railway vehicles - Part 2: Requirements for fire behavior of materials and components
EN 45545-3	Railway applications - Fire protection on railway vehicles - Part 3: Fire resistance requirements for fire barriers
EN 45545-4	Railway applications - Fire protection of railway vehicles - Part 4: Fire safety requirements for railway rolling stock design
EN 45545-5	Railway applications - Fire protection on railway vehicles - Part 5: Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles
EN 45545-6	Railway applications - Fire protection on railway vehicles - Part 6: Fire control and management systems
EN 45545-7	Railway applications - Fire protection on railway vehicles - Part 7: Fire safety requirements for flammable liquid and flammable gas installations
EN 50533:2011	Railway applications - Three-phase train line voltage characteristics CLC/FprTS
50546[1)]	Railway applications - Shore (external) supply system for rail vehicles
EN 60896-22:2004	Stationary lead-acid batteries - Part 22: Valve regulated types - Requirements (IEC 60896-22:2004)
CLC/TS 50534:2010	Railway applications - Generic system architectures for onboard electric auxiliary power systems
CLC/TS 50535:2010	Railway applications - Onboard auxiliary power converter systems
CLC/TS 50537-1:2010	Railway applications - Mounted parts of the traction transformer and cooling system - Part 1: HV bushing for traction transformers
CLC/TS 50537-2:2010	Railway applications - Mounted parts of the traction transformer and cooling system - Part 2: Pump for insulating liquid for traction transformers and reactors
CLC/TS 50537-3:2010	Railway applications - Mounted parts of the traction transformer and cooling system - Part 3: Water pump for traction converters
CLC/TS 50537-4:2010	Railway applications - Mounted parts of the traction transformer and cooling system - Part 4: Gas and liquid actuated (Buchholz) relay for liquid immersed transformers and reactors with conservator for rail vehicles
IEC 60050-482	International Electrotechnical Vocabulary - Part 482: Primary and secondary cells and batteries

1) At draft stage.

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