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Edition 1.0 2020-05

INTERNATIONAL STANDARD

Railway applications – Rolling stock – Batteries for auxiliary power supply systems –
Part 2: Nickel Cadmium (NiCd) batteries

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RAILWAY APPLICATIONS – ROLLING STOCK – BATTERIES FOR AUXILIARY POWER SUPPLY SYSTEMS –

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International Standard IEC 62973-2 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
9/2585/FDIS	9/2594/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62973 series, published under the general title *Railway applications – Rolling stock – Batteries for auxiliary power supply systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

This document considers the requirements for vented or partial recombination Nickel Cadmium (NiCd) batteries following IEC 62973-1:2018.

In this document the interface with a LVPS or charger is specified and the LVPS or charger itself is out of scope.

RAILWAY APPLICATIONS – ROLLING STOCK – BATTERIES FOR AUXILIARY POWER SUPPLY SYSTEMS –

Part 2: Nickel Cadmium (NiCd) batteries

1 Scope

This part of IEC 62973 applies to NiCd rechargeable batteries for auxiliary power supply systems used on railway vehicles. It is an extension of IEC 62973-1:2018 which specifies common requirements for all battery technologies of other parts of IEC 62973. Unless otherwise specified, the requirements of IEC 62973-1:2018 apply.

Battery systems described in this document are used in conjunction with charging systems onboard rolling stock, as described in IEC 62973-1:2018. Charging systems (e.g. LVPS, converters, etc.) are excluded from the scope of this document.

This document also specifies the design, operation parameters, safety recommendations, routine and type tests, as well as marking and designation.

This document is used in addition to IEC 60623:2017 or IEC 62259:2003 for NiCd Cells.

Specific requirements on subcomponents within the battery systems are covered in this document, e.g. temperature measurement components.

When there is an existing IEC standard specifying additional test conditions and requirements for NiCd batteries used in specific railway applications and which conflicts with this document, the latter takes precedence.

The main objective of this document is to achieve standardization of the electrical interfaces by considering NiCd battery parameters to allow for calculating the NiCd battery capacity required for a specific load profile.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60051 (all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

IEC 60077-1, *Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules*

IEC 60623:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Vented nickel-cadmium prismatic rechargeable single cells*

IEC 61373:2010, *Railway applications – Rolling stock equipment – Shock and vibration test*

IEC 62259:2003, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Nickel cadmium prismatic secondary single cells with partial gas recombination*

IEC 62485-2:2010, *Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries*

IEC 62973-1:2018, *Railway applications Rolling stock – Batteries for auxiliary power supply systems – Part 1: General requirements*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

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

Note 1 to entry: Refer to 4.1 and Clause 5.

[SOURCE: IEC 60050-482:2004/AMD1:2016, 482-05-10, modified – Note 1 to entry has been added.]

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

Note 1 to entry: Refer to 4.1 and Clause 5.

[SOURCE: IEC 60050-482:2004/AMD1:2016, 482-02-35, modified – Note 1 to entry has been added.]

3.1.3
cell
basic functional unit of NiCd battery, 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/AMD1:2016, 482-01-01, modified – Note has been deleted and the specific use “of NiCd battery" has been added.]

3.1.4
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

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

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

3.1.5
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/AMD1:2016, 482-05-02, modified – A synonym has been removed.]

3.1.6
rated capacity, <for railway NiCd cell>
C_{n}
capacity value of a battery determined under IEC 60623:2017 specified conditions and declared by the battery manufacturer

3.1.7
state of charge
SOC
remaining capacity to be discharged, normally expressed as a percentage of the full battery rated capacity as expressed in relevant standards

Note 1 to entry: Practical definitions of SOC are dependent upon chosen technologies.

3.1.8
depth of discharge
DOD
capacity removed from a battery during discharge in relation to its full rated capacity expressed as a percentage

Note 1 to entry: It is the complement of SOC.

Note 2 to entry: As one increases, the other decreases by the same amount.

3.1.9
ageing factor, <for railway NiCd cell>
quantitative factor expressing the degradation in the ability of the battery, due to usage, to deliver electrical energy under specified operating conditions such as, but not limited to, operating ambient temperature, cycling considering depth of discharge (DOD), and maintenance practices

3.1.10
nickel cadmium battery information system
electronic system collecting and analyzing battery data to provide additional information, i.e. information not necessary for battery operation

Note 1 to entry: Additional information can be information about e.g. condition-based maintenance.

3.1.11
battery system
battery
system that includes battery tray(s), battery crate(s), monobloc(s), electrical components and/or equipment and associated electromechanical components and connections

3.1.12
end user
organization which operates the battery system

Note 1 to entry: The end user is normally an organization which operates the vehicle equipped with the battery system, unless the responsibility is delegated to a main contractor or consultant.

3.1.13
system integrator
organization which has the technical responsibility of the complete battery system and charging system

Note 1 to entry: The system integrator can be the end user or the train manufacturer, or none of them.

3.1.14
manufacturer, <in railways>
organization which has the technical responsibility for its scope of supply

Note 1 to entry: The manufacturer can be the train builder or the system integrator of a battery system, a cell manufacturer, etc. If necessary to explicitly distinguish, "train manufacturer", "battery system manufacturer" or "cell manufacturer" is expressed.

3.2 Abbreviated terms

AC	Alternating Current
C_n	Capacity at the n-hour rate
CCCV	Constant Current Constant Voltage
DC	Direct Current
DOD	Depth Of Discharge
EMU	Electrical Multiple Unit
FEA	Finite Element Analysis
LVPS	Low Voltage Power Supply
NiCd	Nickel Cadmium
PBE	Plastic Bonded Electrode
SOC	State Of Charge

4 General requirements

4.1 Definitions of components of a battery system, refer to Figure 1 (images are examples)

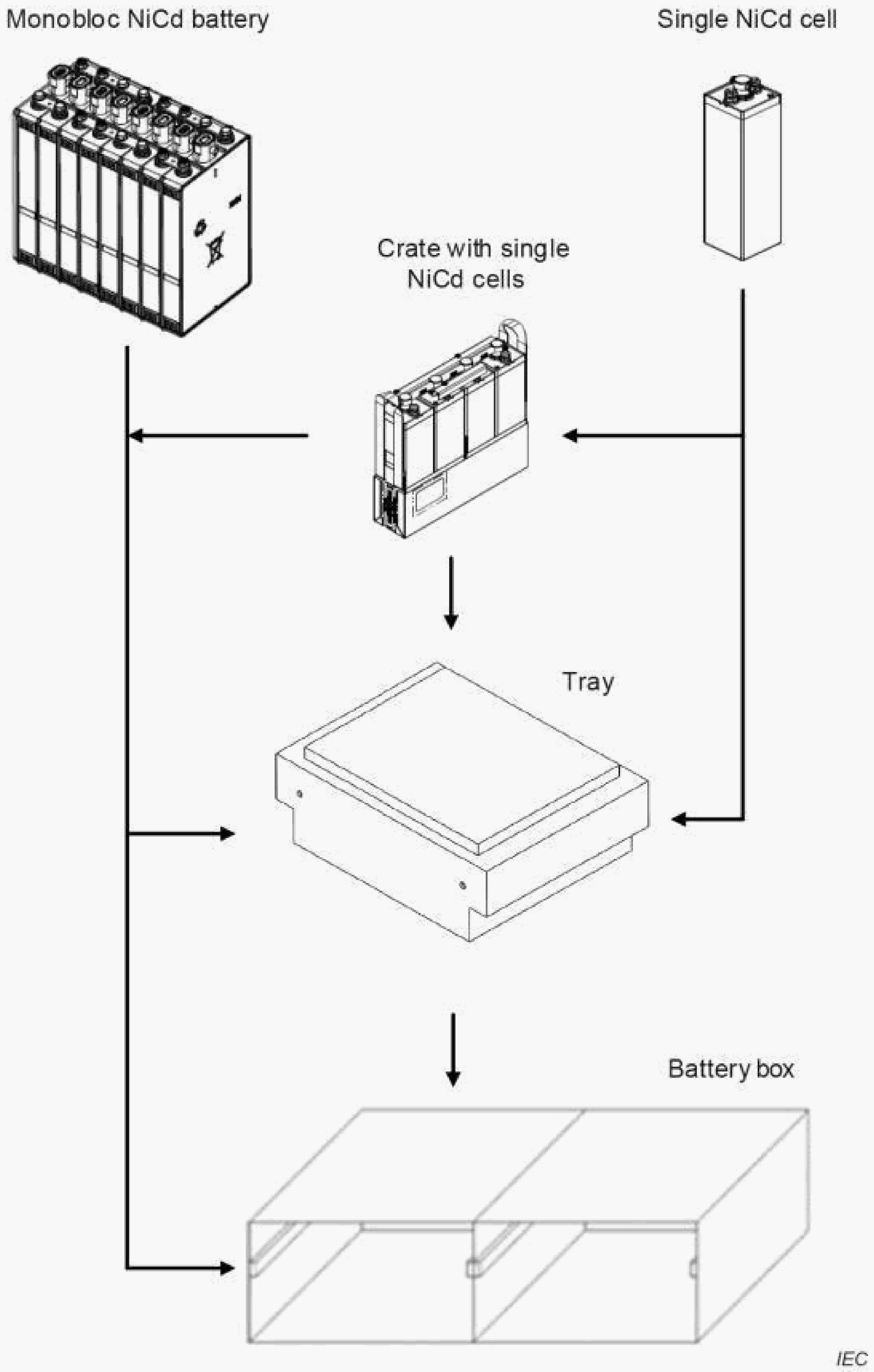


Figure 1 – Definition of NiCd cell(s), monobloc battery, crate, tray, and box

Some batteries may not include all the above components, e.g. single cells may be installed in a tray without crates.

4.2 Definitions of NiCd battery type

4.2.1 General

A battery consists of several cells or monoblocs, and/or assembled in trays, crates, and then assembled in a battery box. Internally, each cell has plate stacks consisting of several positive and negative plates that are separated by a single or multilayer separator. These are held by a supporting structure which in turn are connected to positive and negative terminals that extend to the outside of the cell container.

The positive active material is nickel hydroxide, and the negative active material is cadmium-hydroxide.

The plate stacks are surrounded by alkaline electrolyte, an aqueous solution mainly of potassium hydroxide (KOH), and distilled or deionized water. The electrolyte does not participate in the electrochemical reaction, which takes place in the cell, but only acts as an ion-carrying medium with its specific gravity remaining fairly constant allowing for large electrolyte reserves to be used. The electrolyte does not chemically change or degrade due to charge/ discharge cycles.

Due to NiCd electrochemistry technology, some abuse conditions can be tolerated at the cell level, e.g. overcharging will cause water electrolysis, but only water is consumed. Since there is no chemical change or degradation of electrolyte, it is not necessary to add complex control systems to handle such cases.

4.2.2 Sintered/PBE plate/electrode technology

The sintered positive plate/ electrode is obtained by chemical impregnation of nickel hydroxide into a porous nickel sinter coated thin steel strip that is previously perforated and nickel-plated.

The negative plastic bonded electrode (PBE) is obtained by the coating of slurry consisting of cadmium oxide mixed with a plastic binder onto a nickel-plated thin perforated steel strip.

4.2.3 Sintered/sintered plate/electrode technology

The sintered positive and negative plate/electrode is obtained by chemical impregnation of nickel hydroxide and cadmium oxide into a porous nickel sinter coated thin steel strip that is previously perforated and nickel-plated.

4.2.4 Fiber plate/electrode technology

Both the positive and negative plates/electrodes consist of non-woven fibers of nickel or nickel-plated plastic fibers of high porosity.

4.2.5 Pocket plate/electrode technology

Both the positive and negative plates/electrodes consist of several flat, perforated metal pockets made from perforated steel strips linked together encapsulating the active materials.

4.3 Environmental conditions

NiCd cells/ batteries can perform at extreme temperatures: below –25 °C or above +40 °C.

Especially when at one extreme temperature is specified, deviations for the opposite extreme temperature may be agreed between end user and/ or system integrator and cell/ battery manufacturer.

4.4 System requirements

4.4.1 System voltage

The charging voltage for the NiCd battery is dependent on the number of cells, temperature, and its plate/electrode technology.

Although the nominal battery voltage is set by Table 1 of IEC 62973-1:2018, the number of cells can vary due to the cell charging requirements by their plate/electrode technology.

Due to higher cell charging voltage required by the fiber or pocket plate technology, a lower number of cells can be used in series with a higher capacity. While due to lower charging voltage of sintered/PBE or sintered/sintered plate technology, more cells can be used in series with a lower capacity. Less cells with a higher capacity or more cells with lower capacity would provide similar energy.

The optimised number of cells in a NiCd battery calculated by the battery manufacturer shall allow to operate between the minimum and maximum equipment operating voltage range considering the operating conditions and battery load profile. Then the operational battery charging voltage at 20 °C shall be set considering the calculated number of cells and individual cell charging characteristics. Refer to Table 2.

The NiCd battery nominal voltages and the discharge voltages are different. Figure 2 shows typical discharges of a NiCd cell at different constant discharging currents (shown in multiples of C_n or multiples of I_n, C_n and I_n are related, e.g. 0,2 C_5 is equivalent to I_5) that vary by battery discharge rate designation (e.g. L, M, H per IEC 60623:2017). This discharge curve (discharge voltages relative to discharge capacities based on constant current discharges) shall be available at different temperatures.

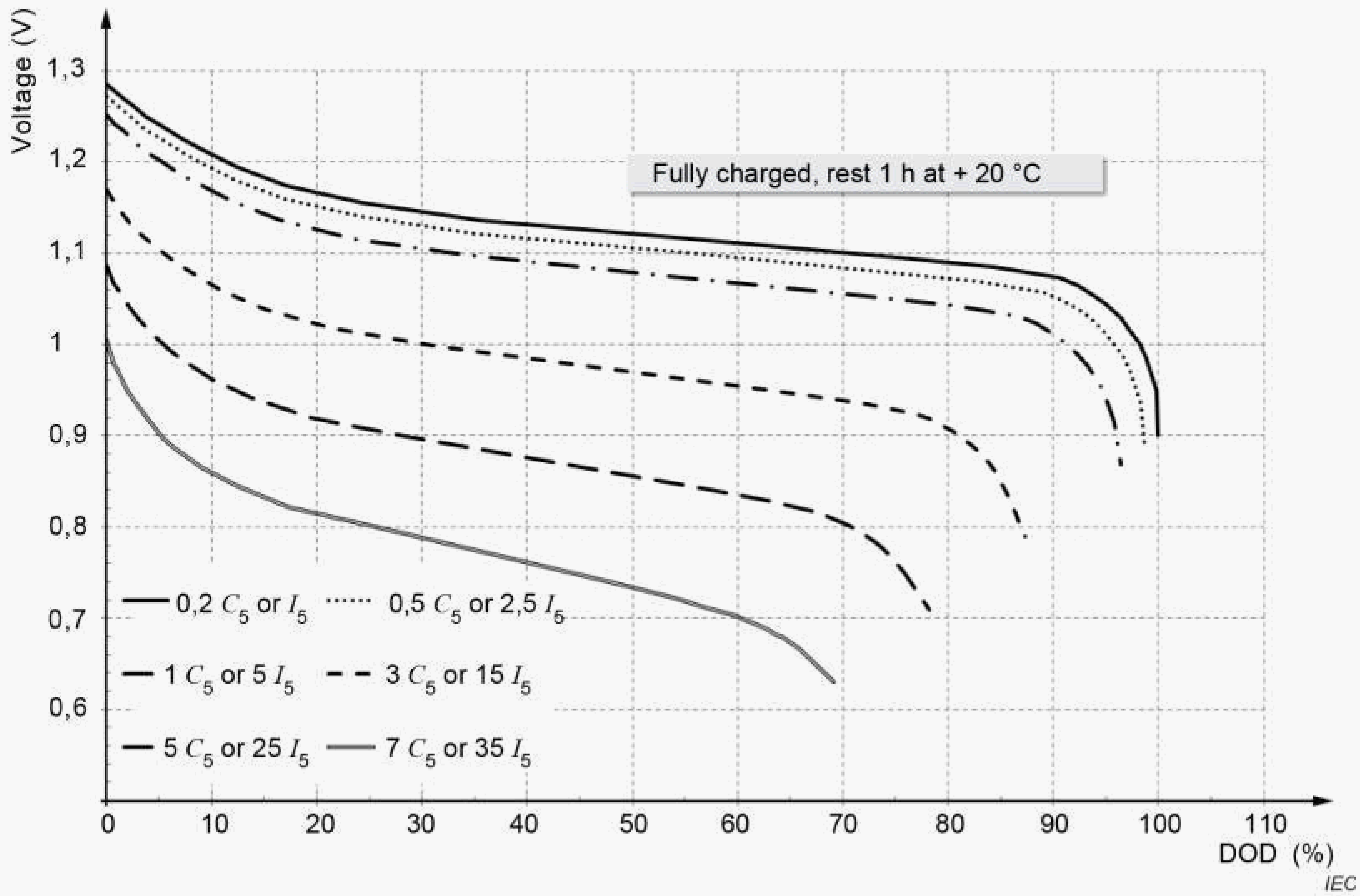
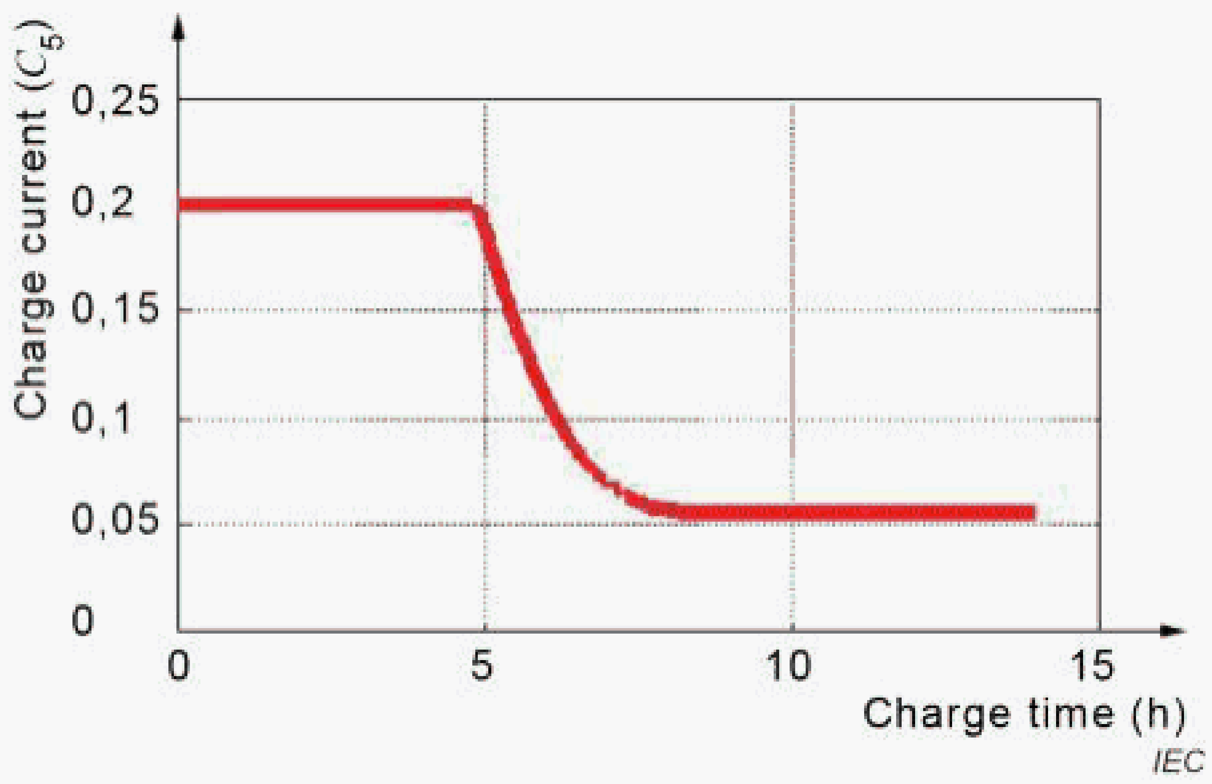


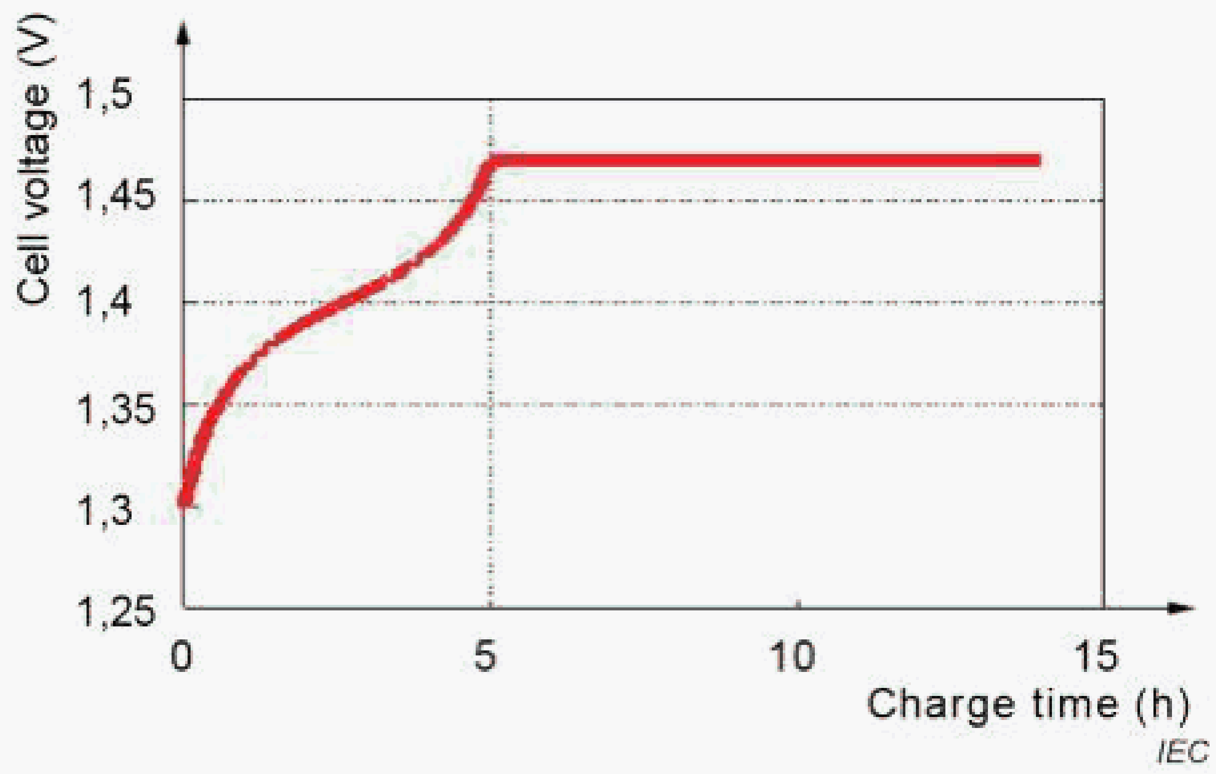
Figure 2 – Example of a NiCd cell discharge curve at various constant discharge currents based on percentage of capacity

The following example, a) in Figure 3 shows a typical charge of a NiCd cell at constant charging current at 0,2 C_5 (equivalent to I_5) for the initial phase followed by b) in Figure 3 constant charging voltage for the last phase depending on the NiCd battery type plate/electrode technology. Charging curves shall be available from battery manufacturers.

Typically, the charging function is performed by the LVPS or charger in a low voltage system architecture.



a) Example of charge current rate curve



b) Example of charge voltage curve

NOTE The positive sign of current in a) in Figure 3 shows the charging condition. When the charge and discharge currents are combined in the same curve, the charge current is depicted with a negative sign opposite to the sign in the load profile as described in Annex A.

Figure 3 – Example of a NiCd cell charge curves

4.4.2 Charging requirements

The required battery charging characteristics and the optimum charging method are specified according to Table 1 and Table 2 respectively.

Table 1 – Requirements of the charging characteristics

Requirements	Characteristics
Normal condition	Float charge by LVPS or charger with temperature compensation.
Charging method	Depending on NiCd battery type plate/electrode technology. Refer to Table 2.
Steady state control tolerance of the battery charge voltage output at the charging system	The charge voltage tolerance refers to the voltage demand according to the ideal charging characteristic of the battery. In case of temperature compensation ± 1,5 % or lower tolerance. Without temperature compensation ± 1 % or lower tolerance.
Charging voltage ripple	≤ 5 % (according to IEC 60077-1 but with disconnected battery).
Charging current ripple	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 shall not exceed values as per IEC 62485-2:2010.
Temperature compensation	Temperature compensation as required by the NiCd battery type plate/electrode technology. Refer to Table 2.
Detection of temperature	Signal from sensor on battery or battery compartment, detection inside battery charging system.

The float and boost charge concept in Table 2 are illustrated in Figure 4.

Table 2 – Typical NiCd battery charging characteristics

NiCd battery charging characteristics		**Float charging voltage at 20 °C**	**Boost charge at 20 °C**	**Remarks**
Basic data for charging (Note 1)	Charging voltage at 20 °C	1,40 V/ cell (Note 2)	1,60 V/ cell (Note 2)	See points ① and ② on Figure 4
	Mandatory, change from boost to float charging	NA	45°C	See point ③ on Figure 4 The switch point from boost to float charge is based on parameters such as temperature, current and/or time
Temperature correction	Typical case with a single value	-3 mV/ cell/ °C (Note 3)	-3 mV/ cell/ °C (Note 3)	See Figure 4
Switching set points (all charge modes)	Mandatory stop charging of battery	Up to 70 °C maximum		See point ④ on Figure 4
	Standard, from boost to float charging	NA	The switch point from boost to float charge is based on parameters such as temperature, current and/or time (Note 4)	Current measurement necessary as well as temperature and/or time
	Standard, from float to boost charging	The switch point from float to boost charge is based on parameters such as temperature, current and/or time (Note 4)	NA	Current measurement necessary as well as temperature and/or time

NOTE 1 When single level charging is used, the boost charge voltage = the float charge voltage.

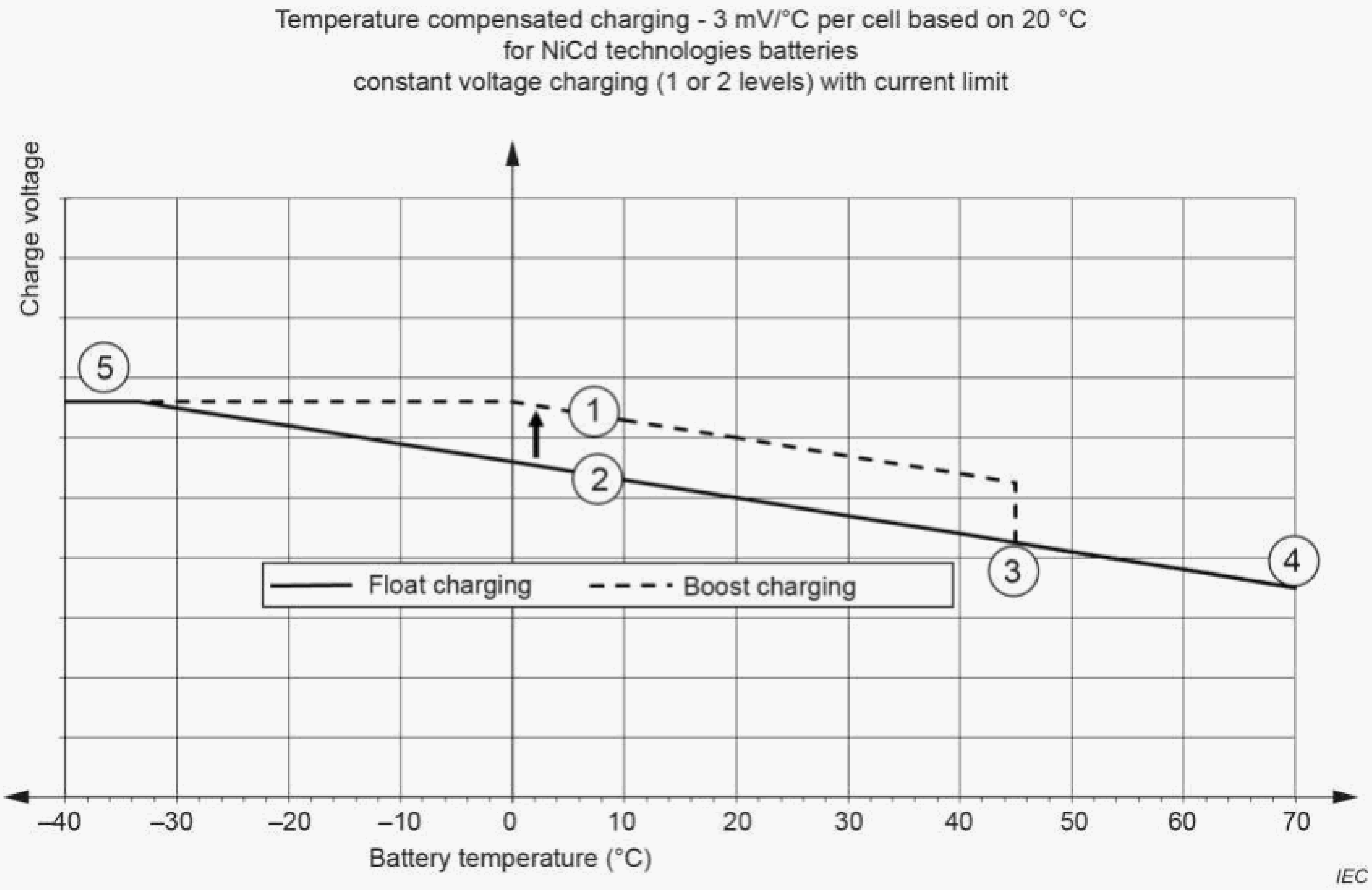
NOTE 2 The values of the charging voltages for the different charge modes are indicative values. The manufacturer can choose different values for reaching a certain state of charge depending on the NiCd technology. Those values are clearly indicated in the cell documentation and available upon request from the cell manufacturer. The voltage tolerance is taken at maximum ±1 %.

NOTE 3 A temperature compensation is necessary, a typical value is of -0,003 V/°C/cell. In case the numerical value is adjusted for some type of cells specified as CCCV, it is clearly indicated in the cell manufacturer's documentation and in the approval documents. It is possible to have 3 values;

- one for temperatures lower than or equal to T_1, ($T_1 \leq 45$ °C, e.g. $T_1 = 20$ °C)
- one for temperature higher than T_1, and lower than or equal 45 °C, and
- one for temperature higher than 45 °C.

NOTE 4 The charging current can vary depending on the designed charging current value as indicated on the documentation provided by the manufacturer for the cell.

NOTE 5 Point ⑤ in Figure 4 corresponds to the maximum charging voltage at the equipment as expressed in Table 1 of IEC 62973-1:2018.



NOTE The location of the temperature sensor is agreed between the end user and battery manufacturer. Refer to 4.5.3.

Figure 4 – Typical NiCd battery charging characteristics

The charging voltage of the battery shall be limited to the maximum voltage at the equipment in Table 1 of IEC 62973-1:2018. The temperature compensation voltage control should be limited to these values considering the charging cell voltage values in Table 2 multiplied by the number of cells in series for the battery.

The typical charging voltages per cell for most applications are shown in Table 2 with temperature compensation voltage control. Higher or lower values, within the above limits, can be selected depending on sizing and application parameters (e.g. in Japan for sintered/PBE, a single level float charge voltage of 1,43 V/cell without temperature compensation voltage control charging is typical).

In some cases, in agreement between the end user and manufacturer, the temperature compensation voltage control charging may not be required. This information shall be agreed upon prior to calculating the battery capacity required for a specific load profile. In such a case, the battery temperature sensor may be omitted. It is the responsibility of the battery manufacturer to calculate the additional battery capacity needed to consider the non-temperature compensated charging regime. In case of extreme low temperature, a heater can be added to limit the additional capacity needed. Then the temperature activation point of the heater shall be agreed prior to battery capacity calculation.

4.4.3 Discharging requirements

4.4.3.1 General

There are different discharging performances for NiCd battery technologies (e.g. sintered/ PBE, sintered/sintered, fiber, pocket plate) while in service or storage affected due to:

– load profile (emergency back-up for auxiliaries and/or during normal operation such as neutral section or power gaps);
– off line discharge when power is not present;

– low and high temperature discharging requirements;
– charge retention (self-discharge);
– deep discharge.

Some of the above discharging requirements are described in the following subclauses.

4.4.3.2 Load profile

The load profile shall be considered for the complete battery. As the number cells can be adjusted to optimize charging, it will influence the load per cell. Refer to 4.4.1. This is to be taken in consideration when calculating the discharge per cell.

4.4.3.3 Extended discharge time

A NiCd battery withstands an extended discharge without permanent damage. Therefore, there is no need for reconditioning to recover the battery performances after this extended discharge.

4.4.3.4 Low or high temperature performance

Discharge performance is characterized at specified low temperature as per IEC 60623:2017, in 7.3.5 or at high temperature in 7.3.6. In case previously performed test results are available at or worse than the requested condition, these can be used without retesting by similarity.

The sizing calculation parameters and temperature derating factor shall be in accordance with the performance characteristics of the battery.

4.4.4 Charge retention (self-discharge)

Self-discharge can lead to a completely discharged NiCd battery over an extended time. However, this does not permanently damage the NiCd battery and it is even recommended to store the battery in a completely discharged state where self-discharge does not occur. A specific condition may be recommended by the cell manufacturer depending on the NiCd technology (e.g. storage in unfilled condition).

The charge retention characteristic is outlined in IEC 60623:2017, 7.4.

For storage of batteries, refer to 8.2.

4.4.5 Requirements for battery capacity sizing

The NiCd battery manufacturer shall define the following parameters according to the NiCd cell technology:

– SOC according to the charging parameters (voltage, temperature compensation, number of cells, battery plate/electrode technology) and environmental conditions,
– ageing factor depending upon but not limited to the operating ambient temperature, cycling at the corresponding DOD, maintenance, and required lifetime.

In case the end user and/ or system integrator dictates any less severe values of the above parameters as proposed by the NiCd battery manufacturer, the result of the operational verification test B.4 in Annex B may not be representative of reality over the lifetime of the battery.

The requirements for battery capacity sizing are specified according to Table 3.

Table 3 – Parameters and responsibility for battery capacity sizing

Parameters needed for battery sizing	Responsibilities of parameters to be provided	Values
Load profile (W, Ω, A)	Provided by the system integrator	Load profile cases each in W, Ω, A over a specified duration period
Low or high temperature for sizing to the load profile (°C)	As specified by the train manufacturer or in conjunction with the end user	High and low temperature in °C as described in 4.4.3.4 of IEC 62973-1:2018
Charging voltage for battery system at 20 °C	Battery or cell manufacturer	Number of cells x requested charging voltage per cell
State of Charge (SOC) at 20 °C under float charging conditions (%)	Provided by the battery or cell manufacturer	Percentage of rated capacity as described in IEC 60623:2017 or IEC 62259:2003 as applicable
Ageing factor (%)	Provided by the battery or cell manufacturer	Percentage of rated capacity as described in IEC 60623:2017 or IEC 62259:2003 as applicable
Requested cycle capability (number of load profile cycles and time duration)	Specified by the end user	Number of cycles and duration (partial or full) of load profile per week, month or year
Useful battery life at an average annual operating temperature of approximately 20 °C under railway conditions (Years)	Provided by the battery or cell manufacturer	Years of life duration under typical railway conditions

End users may require an additional margin, typically expressed as a percentage, for future loads. Unless it is otherwise specified, this margin is applied to the resulting rated capacity of the battery sizing per IEC 60623:2017 or IEC 62259:2003 as applicable.

4.5 Safety and protection requirements

4.5.1 General

The cell container material shall be able to withstand the alkaline electrolyte for the expected battery life. The battery tray or box shall be able to retain alkaline electrolyte in case of battery leakage and withstand corrosion from the electrolyte.

The cell vent plugs or the centralized water filling system, applicable to the NiCd battery technology, shall have flame arrestors to prevent an external flame or spark from entering the cells that can cause an internal explosion which can result in splashing of electrolyte.

The NiCd battery system shall have sufficient ventilation to avoid high and dangerous concentration of gases (refer to 5.6). The calculation of ventilation shall be done according to IEC 62485-2:2010 requirements.

4.5.2 Deep discharge of batteries

Deep discharge of a 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 battery manufacturer.

The typical final discharge voltage is 1,0 V/ cell. All discharge voltages below this value at currents ≤ C_5 indicate a possible deep discharge. Deep discharge should not be confused with cell polarity inversion which means discharging to a negative voltage.

Following a deep discharge when the load is disconnected, the cell voltage will recover above 1,0 V/ cell but it is still in a deep discharged state and shall be charged prior to any additional discharge.

For NiCd batteries a deep discharge will not result in permanent damage nor be a safety issue and therefore, do not require specific devices to protect the battery against deep discharge itself. However, the available capacity especially after repeated deep discharge may be temporarily reduced. Therefore, after a repeated deep discharge the operating instructions of the battery manufacturer shall be followed.

Low voltage cut-off is sometimes installed on trains to protect the train equipment. However, this is not required by the NiCd batteries.

4.5.3 Temperature compensation during charging

The battery charging voltage should be temperature controlled. In practical application, it has been found that temperature compensated charging voltage should be used for NiCd. Refer to 4.4.2.

As a further measure, NiCd charging conditions shall consider both the maximum and minimum operating temperatures.

In case of sensor failure, the battery charging system shall temporarily use a safe default charging value, typically at 20 °C.

The preferred mounting location of the sensor is on a connection between two cells near the middle of the battery. It should be part of the battery system design.

4.6 Fire protection

The fire protection requirements which include flammability resistance, smoke generation and toxicity limits shall be specified by the end user's specification for standard(s) applicable to each country. For some countries the fire protection can be considered at the battery box level. Some examples are provided in the bibliography.

4.7 Maintenance

Maintenance data for preventive maintenance and corrective maintenance shall be available on request from the NiCd battery manufacturer. The maintenance frequency and commissioning of batteries depends on the end user's practices and battery manufacturer's requirements.

A typical maintenance operation includes topping-up electrolyte level at manufacturer's recommended intervals. It is not necessary to decrease the intervals as it can lead to overfilling at levels above the maximum.

4.8 Charging characteristics

Charging characteristics are depended on the NiCd battery technology and are to be selected in a way to ensure a high state of charge under normal operating conditions, and the lowest possible water consumption. Refer to 4.4.2.

4.9 Optional additional components to battery system

4.9.1 General

Some additional components may be added to the battery system to provide either information or providing enhanced battery performance or to assist for additional control to the battery.

4.9.2 Battery information system

A NiCd battery information system can be installed as an option but is not necessary for the battery to operate. This is a separate system to the battery and shall be qualified separately. The battery shall be able to operate without this system.

4.9.3 Battery heater

At extreme low temperatures, a heater can be added to limit the size and additional capacity needed. The battery shall have its temperature raised to the agreed temperature used for the battery capacity calculation.

It is considered that the heater together with the battery has been tested by the battery system manufacturer/integrator to heat the battery from the lowest ambient temperature to the agreed temperature used for the battery capacity calculation.

The battery shall be tested separately to show the capability to perform the load profile at the agreed temperature used for the battery capacity calculation. Refer to Clause B.4 in Annex B.

4.9.4 Thermostat or cut-off switch

To stop the use of the battery above its maximum operational temperature, a thermostat (or cut-off switch) can be installed. This will normally provide a signal to disconnect the battery from the train system to avoid any further charge, refer to point ④ on Figure 4 and Table 2.

The preferred mounting location of the thermostat or cut-off switch is on a connection between two cells near the middle of the battery. It should be part of the battery system design.

5 Mechanical design of battery system

5.1 General

The NiCd battery system can include one or more battery boxes, trays, crates or monobloc batteries. These contain the NiCd cells that are installed in a vertical position, with the terminals on top, to avoid electrolyte leakage. Refer to Clause 4. As it is not necessary to add complex control systems to a NiCd battery, modules are not used with the NiCd battery technology.

5.2 Interface mechanism

All different configurations as described in 5.1 and 5.2 of IEC 62973-1:2018 are used for NiCd batteries.

When a box is also designed to provide fire protection, where applicable, then the box manufacturer or battery system integrator is responsible to comply with the fire protection requirements.

5.3 Location of battery system on the vehicle

For a NiCd battery system, all three of the following locations can apply (this has an impact on the interface of the battery system):

– on the roof (preferred with a centralized watering filling system),
– inside the vehicle (e.g. cabinets, racks),
– underfloor (e.g. low floor, high floor vehicles).

5.4 Accessibility to the battery

For a NiCd battery, all three kinds of access possibilities can apply (this has an impact on the interface of the battery system and maintenance access):

– top (accessibility from the top);

  mounting on the roof or inside the vehicle;

– side (accessibility from one side);

  mounting under the carbody or inside the vehicle;

– across (accessibility from both sides);

  mounting under the carbody.

5.5 Shock and vibration

The NiCd battery, when supported at its designed fixings, shall be able to withstand shock and vibration as stated in IEC 61373:2010.

5.6 Ventilation of battery box

NiCd batteries generate gases during normal operation (e.g. during float or boost charging). Sufficient ventilation is necessary in the battery box to avoid excessive accumulation of gases. The air inlet and outlet openings shall be arranged in such a way that sufficient air flow will be possible especially when the vehicle is stationary (e.g. in the maintenance shop). Natural ventilation is preferred.

The location of the openings on the box depends on box installation location on the vehicle and it shall be defined by end user and/ or system integrator considering the location of the battery.

Refer to IEC 62485-2:2010 for the dimensions of the openings and other requirements. Also follow applicable local regulations. Cell/ battery manufacturer shall provide calculations upon request.

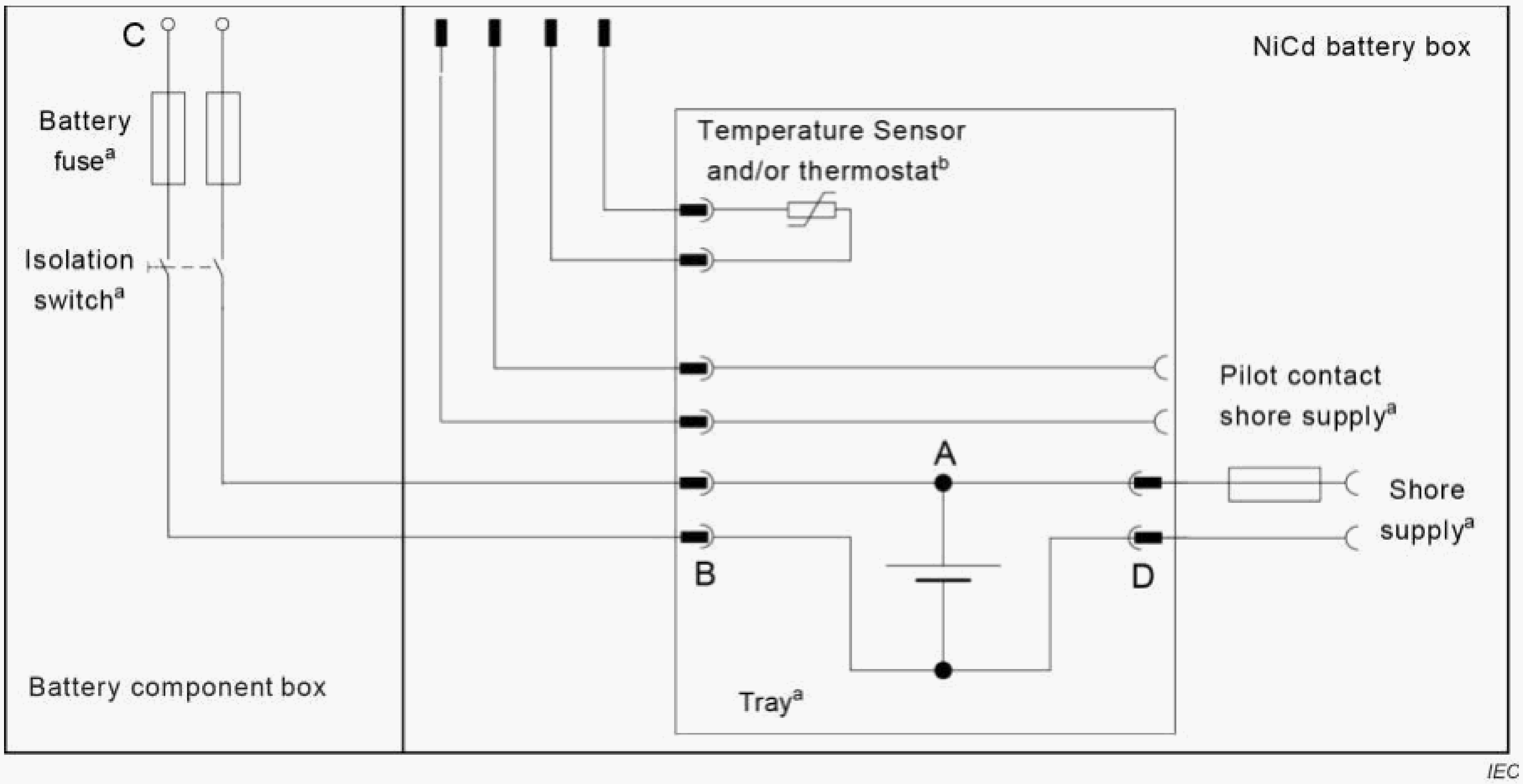
5.7 Water filling system

There are various types of water filling systems such as cells with individual vent plugs opened to top-up with water, or centralized water filling system to top-up from a single location a group of cells. The selected method, as well as interface of the central water filling system if applicable, shall be agreed in advance between the end user and/ or battery system integrator and cell/battery manufacturer.

6 Electrical interface

6.1 General

The following typical electrical interfaces are shown in Figure 5.



Key

A Battery terminal (NiCd cell or monobloc)

B Tray terminal

C Main terminal (complete NiCd battery system)

D Shore supply connector (also possible mounting directly on the tray)

[a] If applicable

[b] Preferred inside the tray on a connection between two cells near the middle of the battery, also possible mounting directly inside the box

Figure 5 – Typical schematic of an electrical interface of a battery system

6.2 External electrical connections interface

Different external electrical connection designs may be used depending on the NiCd battery construction and requirements of the train manufacturer or system integrator as outlined in 6.2 of IEC 62973-1:2018.

7 Markings

7.1 Safety signs

7.1.1 Outside the box

As a minimum, the safety signs as outlined in 7.1.1 of IEC 62973-1:2018 apply.

7.1.2 Tray, crate or other places inside the box

The safety signs as outlined in 7.1.2 of IEC 62973-1:2018 apply.

7.1.3 Cells or monobloc batteries

The marking on cells or monobloc batteries shall comply with IEC 60623:2017.

7.2 Nameplate

7.2.1 Battery box

The nameplate of the box shall include the following information:

– serial number,
– part number,
– weight,
– revision level (if applicable),
– NiCd,
– name of manufacturer.

In some cases, in agreement between the end user and manufacturer, other information such as nominal voltage and rated capacity can be added.

7.2.2 Nameplates on tray, crate or other nameplates inside the box

The NiCd battery nameplate on each tray, crate or other nameplates inside the box shall comply with IEC 62485-2:2010. In case of multiple trays or crates, the numbering sequence and position shall be given either on the trays or crates or in the maintenance manual.

7.2.3 Cells or monoblocs

The marking on cells or monobloc batteries shall comply with IEC 60623:2017.

8 Storage and transportation conditions

8.1 Transportation

Depending on the mode of transportation and local regulations there are different requirements to be followed. The NiCd batteries/cells shall be transported in a vertical position, with the terminals on top, to avoid electrolyte leakage. A specific condition may be acceptable by the cell manufacturer depending on the NiCd plate/electrode battery technology (e.g. transportation in unfilled condition).

8.2 Storage of batteries

For storage, NiCd batteries shall be placed indoors in a dry, clean, frost-free location. It shall not be exposed to direct sunlight. The NiCd batteries/cells shall be stored in a vertical position, with the terminals on top, to avoid electrolyte leakage.

Typically, for a storage duration of more than 3 months, it is recommended to store the NiCd battery in a completely discharged state. A specific condition may be recommended by the cell manufacturer depending on the NiCd plate/electrode battery technology (e.g. storage in unfilled condition).

The storage characteristic test is outlined in IEC 60623:2017, 7.9. In case of new cell model, it is acceptable to place batteries into service prior to this test being completed if all other tests have been completed.

Storage details of each NiCd plate/electrode battery technology shall be specified in the corresponding battery manual.

9 Testing

9.1 General

The basic standards for the NiCd technology are IEC 60623:2017 and IEC 62259:2003. The battery manufacturer shall have completed all tests as outlined in either standard as applicable to the cell type. It is assessed with an official certificate from an accredited authority.

For qualification of a battery manufacturer's model range with a certificate, the selected cell for testing shall be the worst-case electrical performance as declared by the battery manufacturer through an official document as indicated in Clause C.1 of Annex C. In case of no major change in the design of the cells, the initial testing results shall still be accepted when issuing an updated certificate. A major change is a change that affects battery electrical performance (e.g. reducing the number of plates for the same capacity).

Table 4 below shows the typical test categories.

The test procedure and the test parameters shall be specified by agreement between the end user, train manufacturer and battery manufacturer.

There are the following categories of tests:

– type test,

– routine test.

Previous type tests on the same NiCd battery/cell model range shall be acceptable for multiple projects.

Table 4 – Type test and routine test

Test items	Type test	Routine test	Reference
Electrical characteristic tests	Y		9.2.3
Dielectric test	Y		9.2.4
Load profile test	Y		9.2.5
Shock and vibration test	Y		9.2.6
Visual checks		Y	9.3.2
Dielectric test		Y	9.3.3
Electrical characteristic tests		Y	9.3.4

9.2 Type test

9.2.1 General

The type test should include a shock and vibration test of the NiCd battery and a load profile test (load profile according to Annex A).

- By agreement between the end user, the train manufacturer or system integrator and the battery manufacturer the shock and vibration test can be replaced by a calculation, e.g. a finite element analysis (FEA).

- By similarity if a representative smallest test object of a battery manufacturer's model range has been tested, it can be used as a representative for the entire range. The smallest test object is the NiCd cell, battery tray, battery crate, or monobloc. For qualification of a battery manufacturer's model range with a certificate, the selected cell for testing shall be the worst-case shock and vibration behaviour as declared by the battery manufacturer through an official document as indicated in Clause C.2.
- Instead of load profile test, a simulation by calculation from the battery manufacturer can be acceptable (refer to Clause B.5).
- Other relevant tests shall be agreed between the end user, train manufacturer and battery manufacturer.

9.2.2 Parameter measurement tolerances

The overall accuracy of specific measuring instrument for testing the battery system in this document, whichever relative to the specified or to the actual values, shall be within these tolerances:

a) ± 1 % for voltage;

b) ± 1 % for current;

c) ± 2 °C for temperature;

d) ± 0,1 % for time;

e) ± 1 % for dimensions.

These tolerances comprise the combined overall accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

For assistance in selecting instrumentation refer to IEC 60051 for analogue instruments. The details of the instrumentation used shall be provided in any report of results.

Unless other levels of overall accuracies are defined in the subclauses of the individual test document, above accuracies shall apply.

9.2.3 Electrical characteristic tests

Electrical characteristic tests shall be carried out according to the IEC 60623:2017 or IEC 62259:2003 as applicable.

9.2.4 Dielectric test

Dielectric test shall be carried out according to IEC 60077-1.

(refer to IEC 62973-1:2018)

9.2.5 Load profile test

Load profile test shall be carried out based on the agreed profile as described in Annex B.

(refer to IEC 62973-1:2018)

9.2.6 Shock and vibration test

The smallest test object shall be tested according to IEC 61373:2010, Category 1, Class B under its normal fixing conditions and working orientation.

Acceptance criteria: according to IEC 61373:2010.

For the supply of complete NiCd battery assemblies (systems), a shock and vibration test per IEC 61373:2010 or calculation, e.g. FEA shall be performed as agreed between the end user, train manufacturer and battery manufacturer. A calculation, e.g. FEA shall be provided by the battery manufacturer if there is no shock and vibration test performed. In case where testing has been previously carried out on similar or heavier cell, battery crate, monobloc or complete battery system of same technology, same cell manufacturer and same type of assembly, it is not necessary to repeat the shock and vibration test.

It may also be agreed between the end user, and battery manufacturer when replacing other NiCd batteries to use cells, battery crates or monoblocs of known and proven design without testing.

9.3 Routine test

9.3.1 General

A routine test is performed to verify the quality of a batch of delivered NiCd batteries/ cells. The batch acceptance tests shall be based on 10.2 of IEC 60623:2017 or IEC 62259:2003 as applicable or as specified by the end user and/or system integrator.

The number of samples to be tested in a routine test shall be agreed between the end user, train manufacturer or system integrator and battery manufacturer.

9.3.2 Visual checks

Relevant items (e.g. markings) shall be checked according to the agreed drawing(s).

Results shall be as specified in the drawing(s).

(refer to IEC 62973-1:2018)

9.3.3 Dielectric test

Dielectric test shall be carried out according to IEC 60077-1.

(refer to IEC 62973-1:2018)

9.3.4 Electrical characteristics tests

Open circuit voltage shall be verified.

(refer to IEC 62973-1:2018)

Annex A
(informative)

Examples of typical load profiles

A.1 General

Values in the examples below are expressed in constant power load (W), but can also include resistive load (Ω), and constant current load (A).

A.2 Example of load profile – High speed train (Figure A.1)

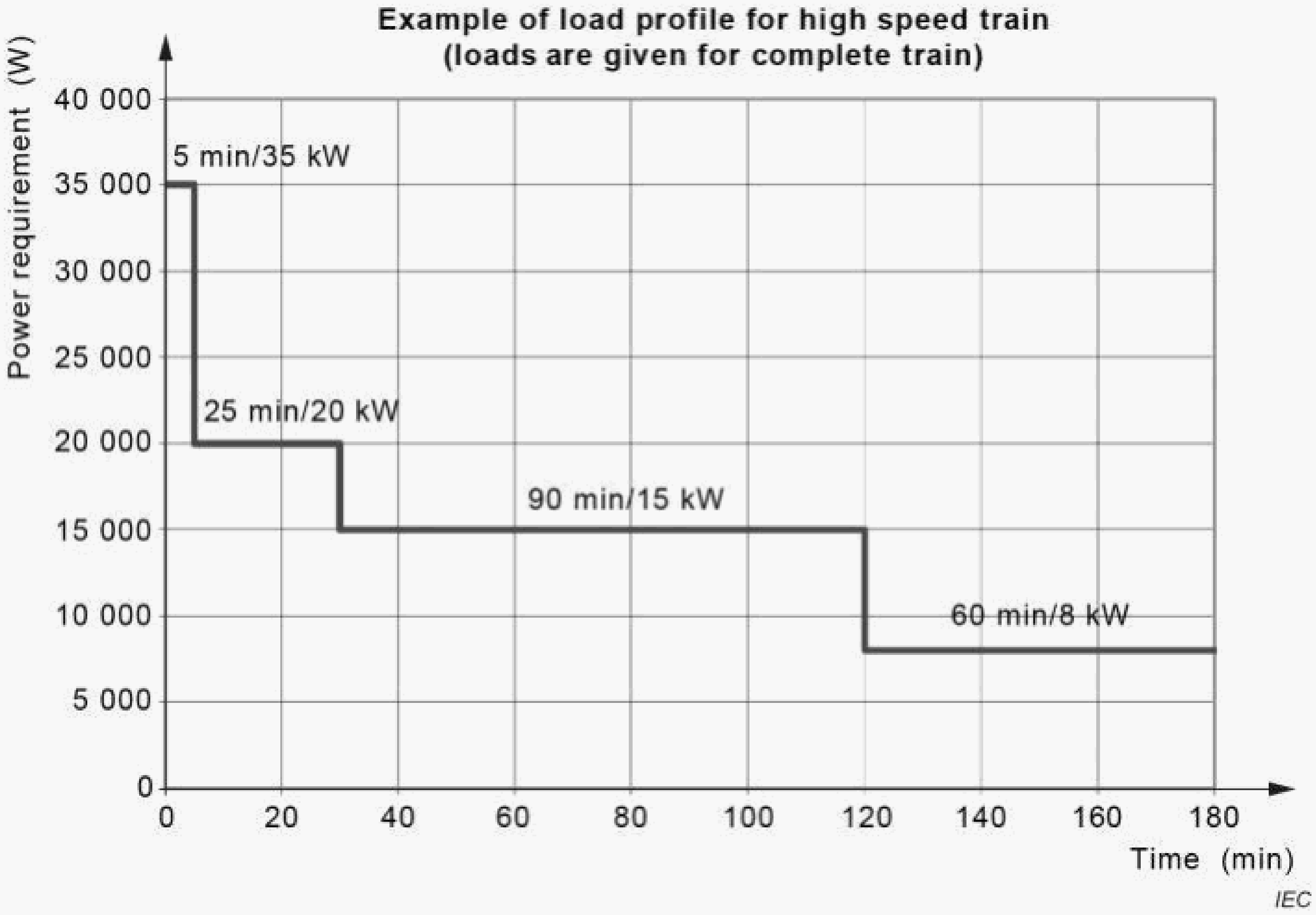


Figure A.1 – Example of load profile for high speed train (without starting up segment)

A.3 Example of load profile – Regional train/ EMU (Figure A.2)

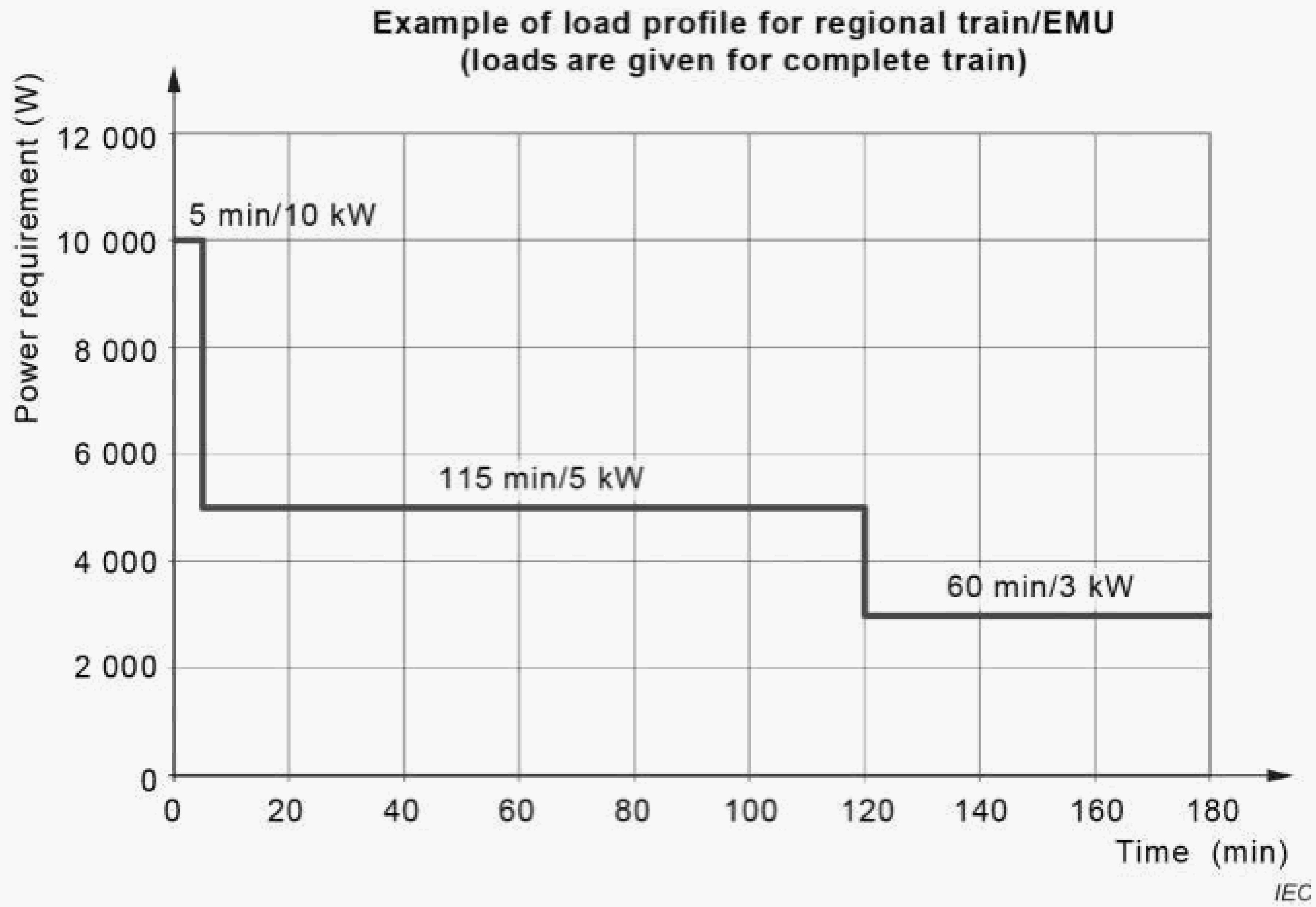


Figure A.2 – Example of load profile for regional train/ EMU (without starting up segment)

Annex B
(normative)

NiCd load profile verification

(refer to IEC 62973-1:2018)

B.1 General

This annex is applicable to specify and verify the NiCd battery capability to supply the requested load profile(s), if specified by the end user and/or system integrator. The aim is to control conformity of design and later verification to the relevant specification. It is recommended that the number of tests are limited to those which are proven and/or agreed upon to be necessary.

NOTE The load profile(s) and the operating conditions are sometimes further optimised during the project.

B.2 General methodology

The NiCd battery sizing of the load profile(s) shall be represented by three types of loads; constant power load (W), resistive load (Ω), and constant current load (A) that may happen at the same time for each discharge time interval. Sometimes not all three types of loads are present.

The methodology and the various parameters shall be specified by agreement between the battery manufacturer, end user and/or system integrator including:

- cumulated discharged energy consumed and available during the load profile,
- power or voltage and current available during the load profile.

In addition, the following parameters shall be taken into account for actual train operation:

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

Load profile(s) shall be initially requested by the end user and/or system integrator, including adjustments to be taken into account between the battery and equipment installed on the train (e.g. voltage drop).

An important part of the methodology is the charge level of the NiCd battery and its ageing, as mentioned in Table 3 depending on the battery technology.

This process requires a well-defined and harmonised methodology to verify load profile compliance. The selected approach has two steps:

- NiCd battery sizing to confirm the compliance of the selected battery for the load profile(s) demanded by the train for the defined environment (temperature) and operational conditions (voltages). The battery sizing can be performed through numerical calculation (e.g. simulation) or laboratory testing if numerical calculation is not available.
- test measurements on selected NiCd battery for compliance verification to the load profile shall be performed under defined simulated conditions.

In case several profiles are requested, all load profiles shall be considered for the sizing. The worst-case load profile along with its parameters shall be identified by the NiCd battery manufacturer and agreed by the end user and/or train manufacturer. Each battery manufacturer shall provide the sizing details to the system integrator during the tendering phase. These sizings shall be available to the end user upon request.

B.3 Battery sizing documentation

The results of the NiCd battery calculations shall be documented. The minimum requirements for the contents of the document(s) are:

- key data for the NiCd battery: plate/electrode technology, cell designation and capacity as per IEC 60623:2017, 5.1 and 7.3.2.2 respectively, quantity of cells in series and parallel,
- environmental conditions (e.g. temperatures for charging, discharging) and derating factors (e.g. ageing, initial SOC depending on the charging conditions),
- charging conditions considering the number of cells in the battery,
- curves that provide the battery behaviour vs. discharge time that show compliance to requested parameters for each load profile for the discharge periods/steps.

B.4 Operational verification (load profile test)

The load profile test is to be performed as agreed between the NiCd battery manufacturer, end user and/or system integrator considering:

- test temperature corresponding to selected sizing,
- minimum representative quantity of cells, battery crates or monoblocs (typically over 10 % of the total cell quantity connected in series corresponding to the number of battery crates or monoblocs). For a NiCd battery sized with a parallel arrangement, the load profile can be adjusted proportionally. The representative quantity of cells will be referred below as "battery" for testing purposes.

The following tolerances are allowed:

- ambient temperature: ± 2 K,
- cells temperature dispersion in the battery: ± 2 K.

NiCd battery preparation:

- cells or battery could be subjected to a suitable number of pre-activation cycles,
- full charge as per 7.2.2 of IEC 60623:2017 or 7.1 of IEC 62259:2003 as applicable,
- application of the derating factors used in agreed battery sizing by performing a partial discharge in relation to the rated capacity C_n (e.g. 90 % ageing and 90 % SOC then 90 % × 90 % = 81 % initial situation, thus a 19 % partial discharge),
- in case additional margin for future loads was required, then a corresponding partial discharge shall be performed in relation to the rated capacity C_n (e.g. 10 % margin then thus a 10 % partial discharge),
- cells or battery should then immediately be installed in chamber to reach agreed temperature, until stable temperature is obtained.

Load profile shall then be performed per agreed battery sizing and all load profile parameters (time, voltage, current, temperature) shall 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.

B.5 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 NiCd battery: plate/electrode technology, cell designation and capacity as per IEC 60623:2017, 5.1 and 7.3.2.2 respectively, quantity of cells in series and parallel,
- environmental conditions (e.g. temperatures for charging, discharging) and derating factors (e.g. ageing, initial SOC depending on the charging condition),
- curves that provide the battery behaviour Vs. discharge time that show compliance to requested parameters for each load profile for the discharge periods/steps,
- description of the measurement equipment used with calibration certificates,
- any observations during the tests which might influence the interpretation of the test results.

In case the test was proportionally adjusted for the lower quantity of cells, it might be necessary to apply a multiple factor to compare the test results to the load profile. In such cases, the proportional adjustment shall be clearly mentioned in the test report.

Annex C
(informative)

Declaration of cell model range representative of the testing

C.1 Electrical performance declaration

We the manufacturer, XXXX, declare that the cell model range type YYYY (capacity from xxx Ah to xxx Ah) electrical performances per IEC60623:2017 or IEC 62259:2003 as applicable can be assessed by testing a representative cell model type NNN (capacity nnn Ah) which is the worst-case in electrical performances.

C.2 Shock and vibration declaration

We the manufacturer, XXXX, declare that the cell model range type YYYY (capacity from xxx Ah to xxx Ah) shock and vibration behaviour per IEC61373:2010 can be assessed by testing a representative cell model type NNN (capacity nnn Ah) which is the worst-case in shock and vibration behaviour.

Bibliography

IEC 60050-482:2004, *International Electrotechnical Vocabulary (IEV) – Part 482: Primary and secondary cells and batteries*
IEC 60050-482:2004/AMD1:2016

IEC 62485-3:2014, *Safety requirements for secondary batteries and battery installations – Part 3: Traction batteries*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

EN 45545-1, *Railway applications – Fire protection on railway vehicles – Part 1: General*

EN 45545-2, *Railway applications – Fire protection on railway vehicles – Part 2: Requirements for fire behaviour of materials and components*

EN 45545-3, *Railway applications – Fire protection on railway vehicles – Part 3: Fire resistance requirements for fire barriers*

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*

CLC/TS 50546, *Railway applications – Rolling Stock – Three phase shore (external) supply system and connectors for rail vehicles*

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*

JIS E 5004-1-2006, *Electric equipment for rolling stock – Part 1: General service conditions and general rules*

NFPA 130, *Standard for Fixed Guideway Transit and Passenger Rail Systems*

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