Batteries Division

ZVEI: Die Elektroindustrie

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Design of flexible cell connectors and battery cables for industrial truck traction batteries and their chargers

1. Introduction

This leaflet contains requirements and design recommendations for electrical cables used for industrial truck traction batteries and their chargers, essentially with reference to existing standards. In addition, design properties and the specific provisions of the battery or cell manufacturer must be respected.

2. Requirements for electrical cables

For industrial trucks, batteries with nominal voltage of 24 V, 36 V, 48 V, 72 V, 80 V, 96 V and 120 V are most commonly used. Batteries with ≥75 V nominal voltage are subject to the Low Voltage Directive 2014/35/EU. The required nominal battery voltage has an essential influence on the selection of the cables. The usual voltages of traction batteries for industrial trucks are below 450/750 V (U_0/U) and accordingly, the requirements of cables as per EN 50525-1 apply. In addition, the cables shall comply with the requirements of the application-specific standards EN 62485-3 and EN 1175.

For the real-world usability of battery cables (one connecting end) and cell connectors (two connecting ends) further requirements must be fulfilled (see following chapters).

2.1 Basic requirements for insulation and flexibility of cables

Cell connectors and battery cables shall be electrically insulated to avoid potential hazards (e.g. short circuit or electrical shock). A cable or connector including connecting end(s) can be considered to be “protected against earth and short circuits“ if the special insulation material and design of the connecting system (see chapter 2.2) ensures the electrical safety of the battery during the whole service life under normal operating conditions. Cell connectors and battery cables shall be selected to be suitable for the operation conditions encountered (voltage, current, bundling of cables). Furthermore connectors and cables shall withstand environmental influences (e.g. temperature, presence of water, electrolyte, dust, hydrogen and oxygen gas, acid aerosol and other chemicals like hydraulic fluids and detergents). Besides environmental influences also resilience for daily use is required to withstand abrasion and tear.

Due to the tight space in industrial trucks and on the battery surface (small bending radii) highly flexible connectors and cables are required. Furthermore the flexibility is essential to ensure the resistance against mechanical stress. This minimizes negative effects from restoring forces as well as vibrations and distortions during operation and battery changing. Also the handling when plugging and unplugging of the battery and vehicle respectively battery and charger is facilitated.

This information leaflet has been developed by the Industrial Batteries Work Group of the ZVEI – Zentralverband Elektrotechnik- und Elektronikindustrie e. V., Batteries Division

Insulation resistance[1]:	***5 kV DC***
Tensile strength of the insulation[2]:	***>15 N/mm²***
	Maximum permissible reduction in tensile strength of 30% over a working period of 5 years
Chemical resistance:	***Sulphuric acid up to a concentration of 50% (corresponds to a density of 1.40 kg/L at 20°C)***
Temperature resistance:	***-30°C to +110°C***
Resistance against mechanical damage:	Scarifying ***the insulation must not result in the tearing trough of the insulation***
Flexibility of the strands[3]:	Fine-***stranded to class 5 or finest-stranded to class 6***

[1] EN 50525-1 table 1 – Requirements for the electrical testing of cables
[2] as per ISO 527-1
3 conductor according to EN 60228

2.2. Requirements for the connector system

The function of a connector system is to ensure a permanent low-resistance electrical connection from cell to cell (connector) and battery to plug (battery cable). Therefore corrosion must be avoided at the contact points or along the length of the electric conductor path at any time. Corrosion will lead to significant increase of the contact resistance and potentially critical operational states. In extreme cases, a critical operational state can lead to the risk of fire and explosion hazards.

In order to reliably protect the conductive contact points from exposure to corrosion-promoting substances (water, electrolyte, acid aerosol, etc.) over the entire battery life, connector systems with integrated gaskets are well proven.
A sealed connector system with integrated gasket consists of: cable, over-moulded connecting end, screw and terminal (figure 1). The connector system shall not require retightening of the terminal screw throughout the lifespan of the battery.

Not sealed, untightened screw

Sealed after tightening the screw

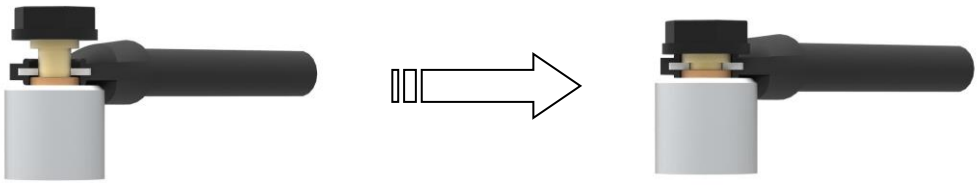

Figure 1: Example of a connector system before and after assembly (cable, over-moulded connecting end, screw and terminal)

2.3 Electric Resistance

The total electric resistance of a single cell connector should be smaller than the resistance of the corresponding connector cable with the addition of 2 x 10 µΩ for contact resistance at the point of contact (measurement points as shown in figure 2).

1 - Measurement points, connector voltage drop
2 - Measurement points, temperature
3 - Measurement points, connector cable voltage drop

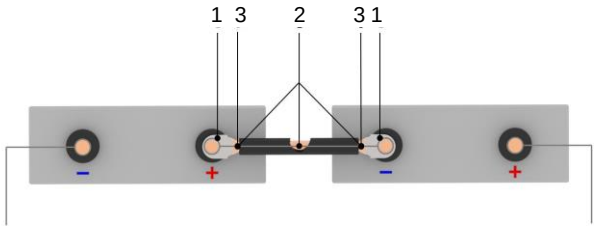

Figure 2: Position of the measurement points for determining a specific voltage drop at a connector

2.4 Ampacity

A current flowing in a conductor causes heating. The maximum permissible temperature is determined by the thermal resistance of the insulation material of cell connector and battery cable. Effects caused by cell design and type as well as the battery layout must be taken into account. Correspondingly the determination of the connector diameter for the operational battery current can vary by manufacturer. As a standard, the 2-hour battery current (I_{2h}) is taken as the rated current or operational current.

Simplified calculation of the 2-hour battery current (I_{2h}):

$I_{2h} = 0.8 \times C_{5h} / 2h$

C_{5h} = 5-hour battery capacity [Ah]
= Nominal capacity of the battery as per nameplate [Ah]

The cable diameter must be selected in accordance with the specific ampacity of the connector or cable in order to avoid inadmissibly high temperatures of the cable insulation. In this respect, the battery manufacturer may deviate from the ordinary assignments stipulated in EN 50565-1 (VDE 0298-565-1). For such deviations the individual connector configuration and cell arrangement has been tested and evaluated by the battery manufacturer.
However, special application conditions or non-standard current profiles may need a higher conductor cross-section. In particular, discharge current peaks, recuperation currents and high charging currents (fast charge) must be taken into account when selecting a connector or cable diameter.

2.5 Labelling of cell connectors an battery cables

The rated voltage and insulating material definition must be marked legibly and durably to connectors and cables. On cell connectors this is recommended but may not always be possible for technical reasons (connector length). At least the cable diameter shall be marked down legibly and durably to all cell connectors.

3. Reference to standards

The following cited documents are required for the application of this document. As regards dated references, only the edition referred to is valid. As regards undated references, the latest edition of the document referred to (as amended) applies.

3.1 Relevant Standards

EN 50525-1 Electric cables - Low voltage energy cables of rated voltages up to and including 450/750 V (U_0/U) - Part 1: General requirements

EN 50565-1 Electric cables - Guide for use of cables with a rated voltage not exceeding 450/750 V (U_0/U) - Part 1: General guidance

EN 1175-1 Safety of industrial trucks - Electrical requirements - Part 1: General requirements for battery powered trucks

EN 62485-3 Safety requirements for secondary batteries and battery installations - Part 3: Traction batteries for industrial trucks

DIN EN 60228 Conductors of insulated cables

3.2 Informative References

2014/35/EU Low Voltage Directive from 20 April 2016

EN 60204-1 Safety of machinery - Electrical equipment of machines - Part 1: General requirements

43531 Lead-acid batteries - Traction batteries 48 V with cells of dimension series L in accordance with EN 60254-2 for industrial trucks - Dimensions, weights, design

DIN 43535 Lead-acid batteries - Traction batteries 24 V with cells of dimension series L in accordance with EN 60254-2 for industrial trucks - Dimensions, weights, design

DIN 43536 Lead-acid batteries - Traction batteries 80 V with cells of dimension series L conforming to EN 60254-2 for industrial trucks - Dimensions, weights, design

DIN 43537 Lead-acid batteries - Traction batteries 24 V, 36 V, 48 V, 72 V, 80 V with cells of dimension series E for industrial trucks conforming to EN 60254-2 - Dimensions, weights, design

EN 50363 Insulating, sheathing and covering materials for low voltage energy cables - Part 0: General introduction

DIN VDE 0623-589 Plug-in devices for battery powered industrial trucks, Type 80, 160, 320, 640 / 150 V - Part 589: Dimensions of plug-in device, material, marking

ZVEI leaflet 9-1 Dimensions, assignment and design of connector systems and cables for traction batteries and charging devices

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